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HARMOGRAV. A SPHERICAL HARMONIC FUNCTION TO REPRESENT THE EARTH--ETC(U)
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HARMOGRAV
A SPHERICAL HARMONIC FUNCTION TO REPRESENT THE EARTH'S GRAVITATIONAL POTENTIAL

June 1975

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distribution unlimited

DEFENSE MAPPING AGENCY
AEROSPACE CENTER
ST. LOUIS AIR FORCE STATION, MISSOURI 63118

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HARMOGRAV

A SPHERICAL HARMONIC FUNCTION TO REPRESENT THE EARTH'S GRAVITATIONAL POTENTIAL

June 1975

by
Vojislav/Dimitrijevich
Geodetic and Geophysical Products Branch

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AEROSPACE CENTER
ST LOUIS AIR FORCE STATION, MISSOURI 63118

PREFACE

GENERAL: This publication is one of a series of reports on achievements related to the fields of mapping, charting, and geodesy, and their related arts and sciences. Each report is written by a Defense Mapping Agency Aerospace Center technician qualified by training and experience to contribute knowledge and technology to the selected subject.

PURPOSE: To contribute technical information to the field of geodesy by describing the results of a study that employs a novel technique to define a global terrestrial gravity model from available observed data.

DISCLAIMER: This report represents the research and experimentation of the author and does not necessarily reflect the official sanction of the Defense Mapping Agency Aerospace Center.

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ABSTRACT

A new way to estimate a composite earth gravity model, representing 5° x 5° equal area gravity anomalies, by harmonic coefficients of the earth's gravity potential is demonstrated. This earth gravity model represents a pure terrestrial gravitational potential, developed by conventional mathematical formulas. The observational data used in the development was restricted to mean gravity anomalies derived from surface gravity measurements. The mean gravity anomalies representing the unsurveyed sectors adjacent to surveyed sectors are allowed to take on values which are determined from a previously derived potential function that was developed from all previously established anomaly values and from zero anomaly values for all unestablished sectors. As each new potential function is developed from the already established sector means, that function is used to compute and fix the mean anomaly values for the next step of unsurveyed adjacent sectors. Thus, by successively fixing the means of the adjacent sectors and by always holding to the originally observed sector values, a full set of fixed means and a final potential function can be developed.

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I. INTRODUCTION

This paper presents a procedure for developing a spherical harmonic function to represent the earth's gravitational potential. The observational data used in the development was restricted to gravity anomalies derived from surface gravity measurements. The function was developed to degree 36 and order 36. Five degree by five degree equal area free-air gravity anomalies were used in the development of the coefficients. The function has been named HARMOGRAV.

II. DETERMINATION OF 5° x 5° EQUAL AREA SECTORS

The earth is assumed to have a surface area of 510,070,290 km^2 [1]. Dividing the earth into 1660 equal areas, a 5° x 5° square at the equator has a surface area of 307,350 km^2. The equal area subdivision of the earth is shown in Table 1, and in Figures 1 and 2. The centroid positions of the squares were computed in accordance with square surfaces.

III. CONVERSION OF GRAVITY ANOMALIES FROM INTERNATIONAL FORMULA - POTSDAM SYSTEM TO GEODETIC REFERENCE SYSTEM 1967 (GRS 67) [2]

It was decided that HARMOGRAV would be referred to the GRS 67 Gravity Formula - absolute system, but all mean free-air gravity anomalies available at the start of the development were referred to the International Gravity Formula - Potsdam System. To perform the conversion from the Potsdam system to an absolute system, it was necessary to determine an absolute gravity formula for the International Ellipsoid. The adopted correction to gravity at the equator in the Potsdam system was -14 mgals. Adding this correction, the gravity at the equator for the International Gravity Formula is:

Table 1

Division of the Earth's Surface
Into Equal Area 5° x 5° Sectors

Band	Latitude Maximum	Latitude Minimum (In Degrees)	Latitude Centroid	Longitude Width	N Number of Sectors North	N Number of Sectors South	NSQ Sector Identification's Number North	NSQ Sector Identification's Number South
1	90.0	85.1488	86.5702	120.0	3	3	1-3	1658-1660
2	85.1488	79.8903	82.0737	36.0	10	10	4-13	1648-1657
3	79.8903	74.8743	77.1398	22.5	16	16	14-29	1632-1647
4	74.8743	70.0933	72.3269	17.1428	21	21	30-50	1611-1631
5	70.0933	65.0598	67.4435	12.8572	28	28	51-78	1583-1610
6	65.0596	60.0008	62.4237	10.5883	34	34	79-112	1549-1582
7	60.0008	55.0129	57.4424	9.2308	39	39	113-151	1510-1548
8	55.0129	50.0388	52.4562	8.1819	44	44	152-195	1466-1509
9	50.0388	45.0407	47.4809	7.3469	49	49	196-244	1417-1465
10	45.0407	39.9901	42.4651	6.6667	54	54	245-298	1363-1416
11	39.9901	35.0306	37.4698	6.3159	57	57	299-355	1306-1362
12	35.0306	30.0314	32.4969	5.9017	61	61	356-416	1245-1305
13	30.0314	24.9631	27.4687	5.5385	65	65	417-481	1180-1244
14	24.9631	20.0180	22.4689	5.4547	66	66	482-547	1114-1179
15	20.0180	15.0055	17.4949	5.2175	69	69	548-616	1045-1113
16	15.0055	10.0350	12.5086	5.1428	70	70	617-686	975-1044
17	10.0350	4.9987	7.5097	5.0	72	72	687-758	903-974
18	4.9987	0.0	2.4970	5.0	72	72	759-830	831-902
				$\sum$	1660			

NORTHERN HEMISPHERE

5°x 5° EQUAL AREA SECTORS

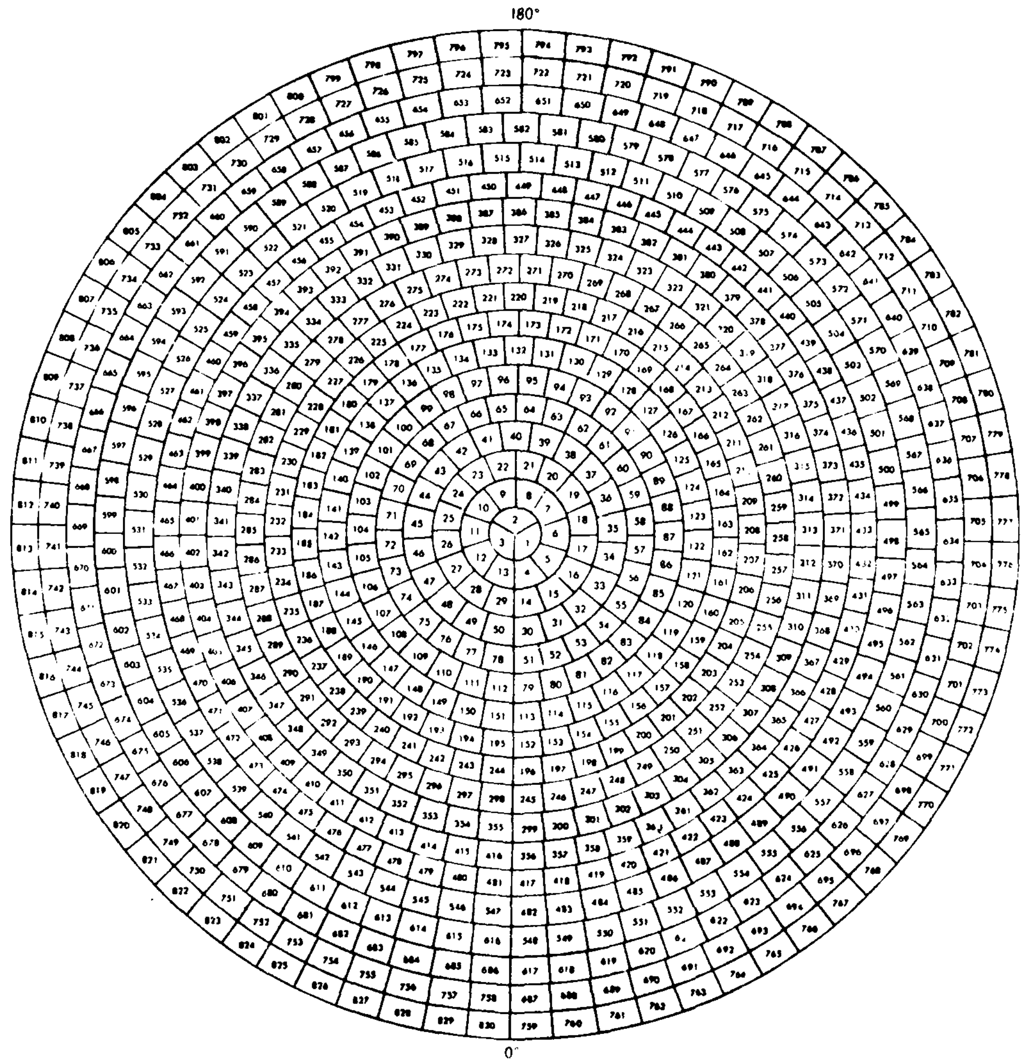
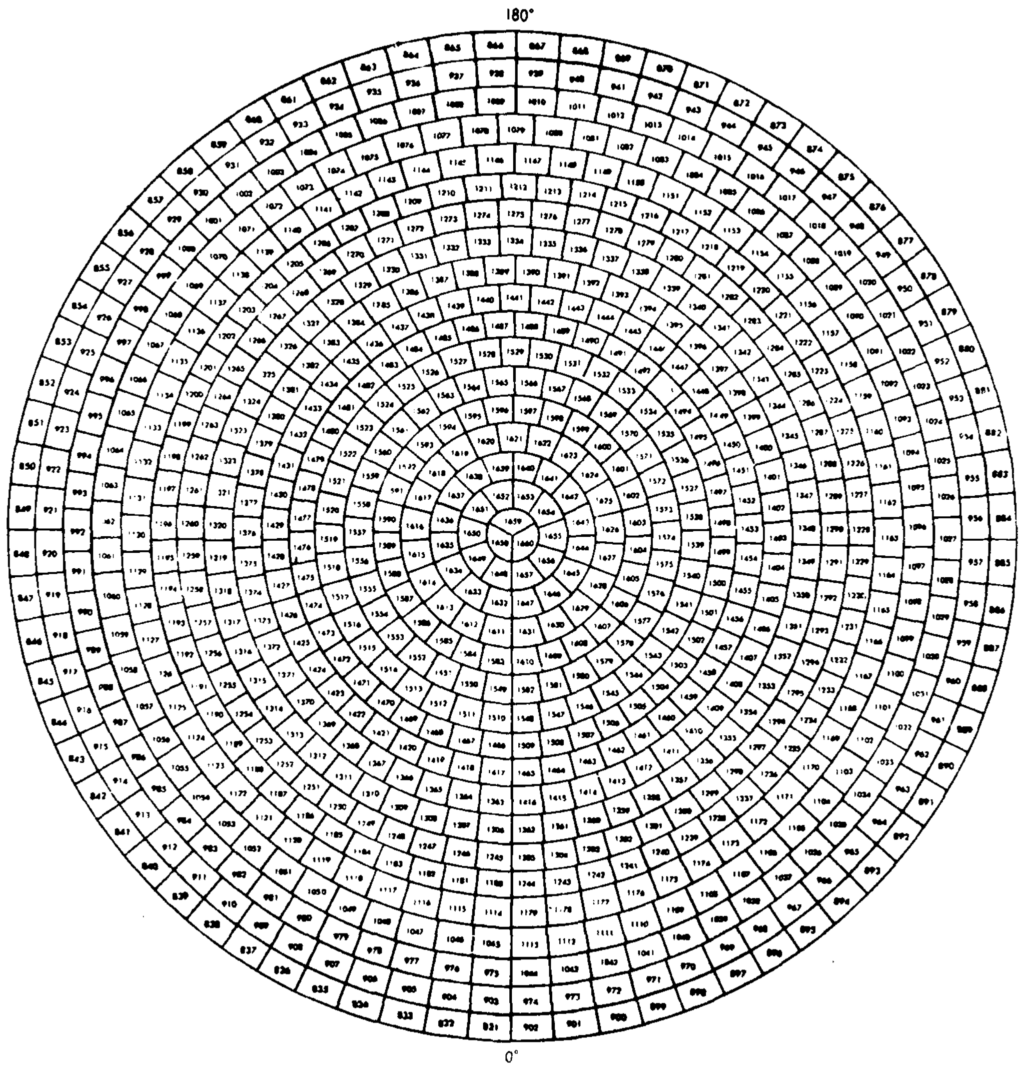


FIGURE 1

SOUTHERN HEMISPHERE

5° x 5° EQUAL AREA SECTORS



F RE

$$\gamma_e = 978035.0 \text{ mgals}$$

The gravity formula parameters β and ε were determined using the well known formulas of Clairaut [3]

$$\beta = 5/2c - f - 17/14\, cf$$

$$\varepsilon = -5/8fc + 1/8\, f^2$$

where

$$c = \frac{\omega^2 a}{\gamma_e}$$

ω = earth's angular velocity

a = semimajor axis of the ellipsoid

f = flattening of the ellipsoid

Then

$$\beta = 0.00528851$$

$$\varepsilon = -0.00000587$$

The absolute gravity formula for the International Ellipsoid is, therefore

$$\gamma = 978.035(1 + 0.00528851 \sin^2\phi - 0.00000587 \sin^2 2\phi) \text{ cm sec}^{-2}$$

The following parameters are related to this formula

$$GM = 3.986273 \times 10^{14} \text{ m}^3 \text{ sec}^{-2}$$

$$\bar{C}_{20} = -488.3796 \times 10^{-6}$$

$$\bar{C}_{40} = 0.782267 \times 10^{-6}$$

A correction graph for converting gravity anomalies from the International Gravity Formula - absolute system to the GRS 67 Gravity Formula is shown in Figure 3.

IV. INPUT DATA

Gravity anomalies for this project were obtained from the DMAAC tape file of 1° x 1° mean free-air anomalies dated Nov 1972. Only those mean anomalies bearing the following code denotations were selected.

- 0 (Simple average from observation);
- 3 (Bouguer anomaly map estimates);
- 4 (Free-air anomaly map estimates);
- A (Average of smaller size squares);
- B (Modified simple average free-air);
- M (Modified average free-air).

The accepted 1° x 1° mean free-air anomalies were weighted using the formula

$$\frac{\Sigma \Delta g \times \cos\phi}{\Sigma \cos\phi}$$

to form equal area 5° x 5° mean free-air gravity anomalies. Over all the world, 1337 of the equal area sectors had observed gravity anomalies while 323 were void. Mean values for 225 sectors were rejected because they did not contain a sufficient number of 1° x 1° values possible within the sector. Section V discusses the means used for the void and rejected sectors.

The geometric and gravimetric parameters of the GRS 67, as given below, were used throughout the computations [2].

CORRECTION GRAPH
FROM INTERNATIONAL (1930) TO GRS (1967)
(Absolute Gravity Formula)

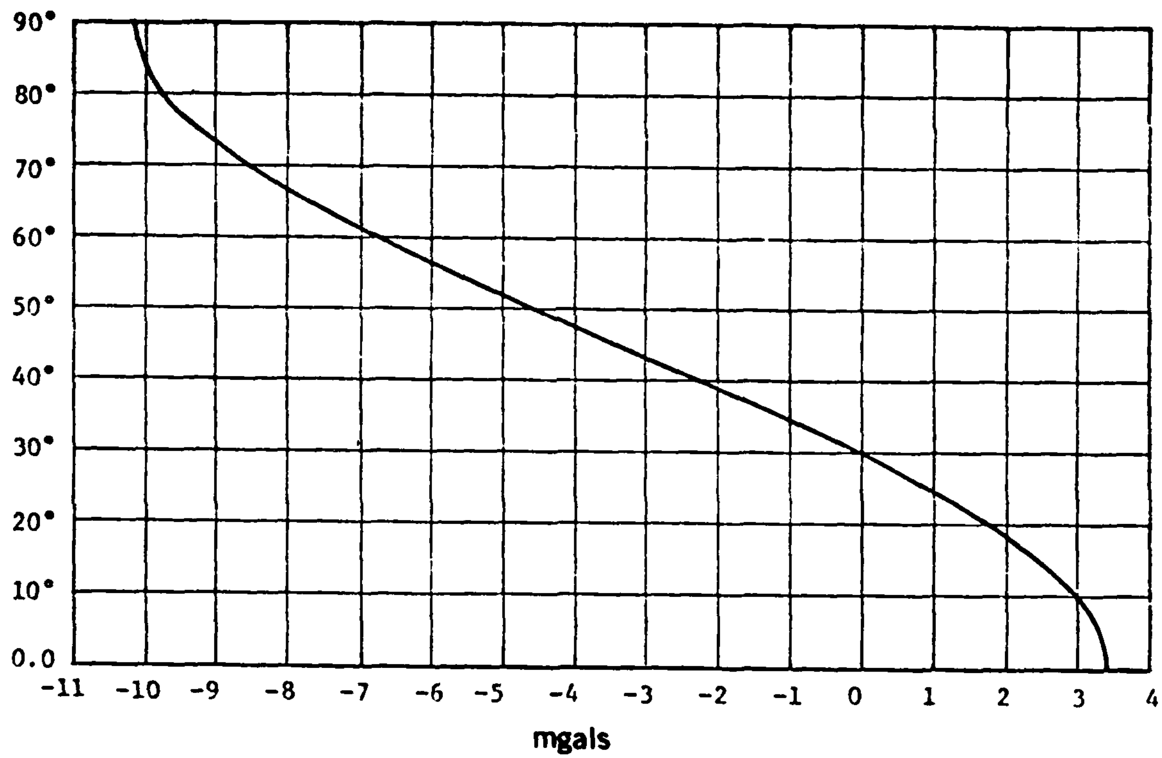


FIGURE 3

$$a = 6378160\text{m}$$

$$b = 6356774.516\text{m}$$

$$f = 1/298.24717$$

$$GM = 3.98603 \times 10^{14}\text{m}^3\text{sec}^{-2}$$

$$J_2 = 1082.7 \times 10^{-6}$$

$$\gamma = 978.0318\ (1 + 0.0053024\sin^2\phi - 0.0000059\sin^2 2\phi)\ \text{gal}$$

V. THE FUNDAMENTAL ASSUMPTION

It is necessary to accept a hypothetical solution for the gravity anomalies which represent the sectors without values. The resulting function will depend on the hypothesis which is utilized in this paper. The mean gravity anomalies representing the unsurveyed sectors adjacent to surveyed sectors are allowed to take on values which are determined from a previously derived potential function that was developed from all previously established anomaly values and from zero anomaly values for all unestablished sectors. As each new potential function is developed from the already established sector means, that function is used to compute and fix the mean anomaly values for the next step of unsurveyed adjacent sectors. Thus, by successively fixing the means of the adjacent sectors and by always holding to the originally observed sector values, a full set of fixed means and a final potential function can be developed. The final function will reproduce the original mean anomalies with minimum distortion.

VI. PROCEDURE

The gravity values in this project were referred to the GRS 67 Gravity Formula. All 1112 sector mean free-air gravity anomalies were converted from the International Potsdam system to the GRS 67 absolute system. These mean free-air gravity anomalies were then expanded into spherical harmonic coefficients to degree and order 36. Starting with the 1112 sector gravity anomalies with non zero values and the remaining 548 sectors with unknown values, which were assumed to be zero, the conventional harmonics were computed as follows:

$$A_{no} = \frac{2n+1}{1660} \sum_{k=1}^{1660} \Delta g_k \, P_{no} \, (\sin\phi_k)$$

$$B_{no} = 0$$

$$\left.\begin{matrix} A_{nm} \\ B_{nm} \end{matrix}\right\} = \frac{2(2n+1)}{1660} \times \frac{(n-m)!}{(n+m)!} \sum_{k=1}^{1660} \Delta g_k \, P_{nm} \, (\sin\phi_k) \begin{Bmatrix} \cos m\lambda_k \\ \sin m\lambda_k \end{Bmatrix}$$

The potential coefficients, C and S, were computed from the formula

$$\left.\begin{matrix} C_{nm} \\ S_{nm} \end{matrix}\right\} = \begin{Bmatrix} A_{nm} \\ B_{nm} \end{Bmatrix} (n-1) \; \frac{GM}{a^2}$$

and the normalized coefficients were computed as follows:

$$\begin{Bmatrix} \bar{C}_{nm} \\ \bar{S}_{nm} \\ \bar{A}_{nm} \\ \bar{B}_{nm} \end{Bmatrix} = \begin{Bmatrix} C_{nm} \\ S_{nm} \\ A_{nm} \\ B_{nm} \end{Bmatrix} \times \left[\frac{(n+m)!}{(n-m)!\ (2n+1)\delta} \right]^{\frac{1}{2}}$$

where

$$\delta = 1 \text{ if } m = 0$$

$$\delta = 2 \text{ if } m \neq 0$$

The determined set of coefficients was then used to compute a new set of gravity anomalies using the formulation

$$\Delta g = \sum_{n=2}^{36} \sum_{m=0}^{n} \left(\frac{a}{r}\right)^n (A_{nm} \cos m\lambda + B_{nm} \sin m\lambda)\ P_{nm}(\sin\phi) .$$

The next step in developing the harmonic model was the recomputation of a new set of harmonic coefficients using a new set of gravity anomalies which consisted of the original 1112 sectors with the originally observed mean free-air gravity anomalies, 68 sectors whose original zero values were replaced with the values obtained using the first set of coefficients (these sectors were between or adjacent to the observed or computed values), and 480 sectors with zero values. The new set of harmonic coefficients (36,36) were then used to establish a new of set of 1660 sector gravity anomaly values. Values from this set were then used to replace the zero values only for those sectors adjacent to the previously observed or adopted values. This process of slowly replacing the zero values was continued thru 12 more iterations. The final set of 1660 5° x 5° equal area mean free-air gravity anomalies is shown in Appendix A.

VII. RESULTS

The standard deviation between the mean free-air gravity anomalies of the final gravity model and the original set of input gravity data is 2.63 mgals.

$$\sigma = [(\text{new} - \text{old})^2/1659]^{\frac{1}{2}}$$

The δC_{20} coefficient computed from the final set of gravity anomalies is 0.1608×10^{-7}, and the computed dynamical form factor of the earth is

GRS 67 adopted value	J_2	=	0.001082700 [2]
correction	$-\delta C_{20}$	=	-0.000000016
This gravity model value	J_2	=	0.001082684

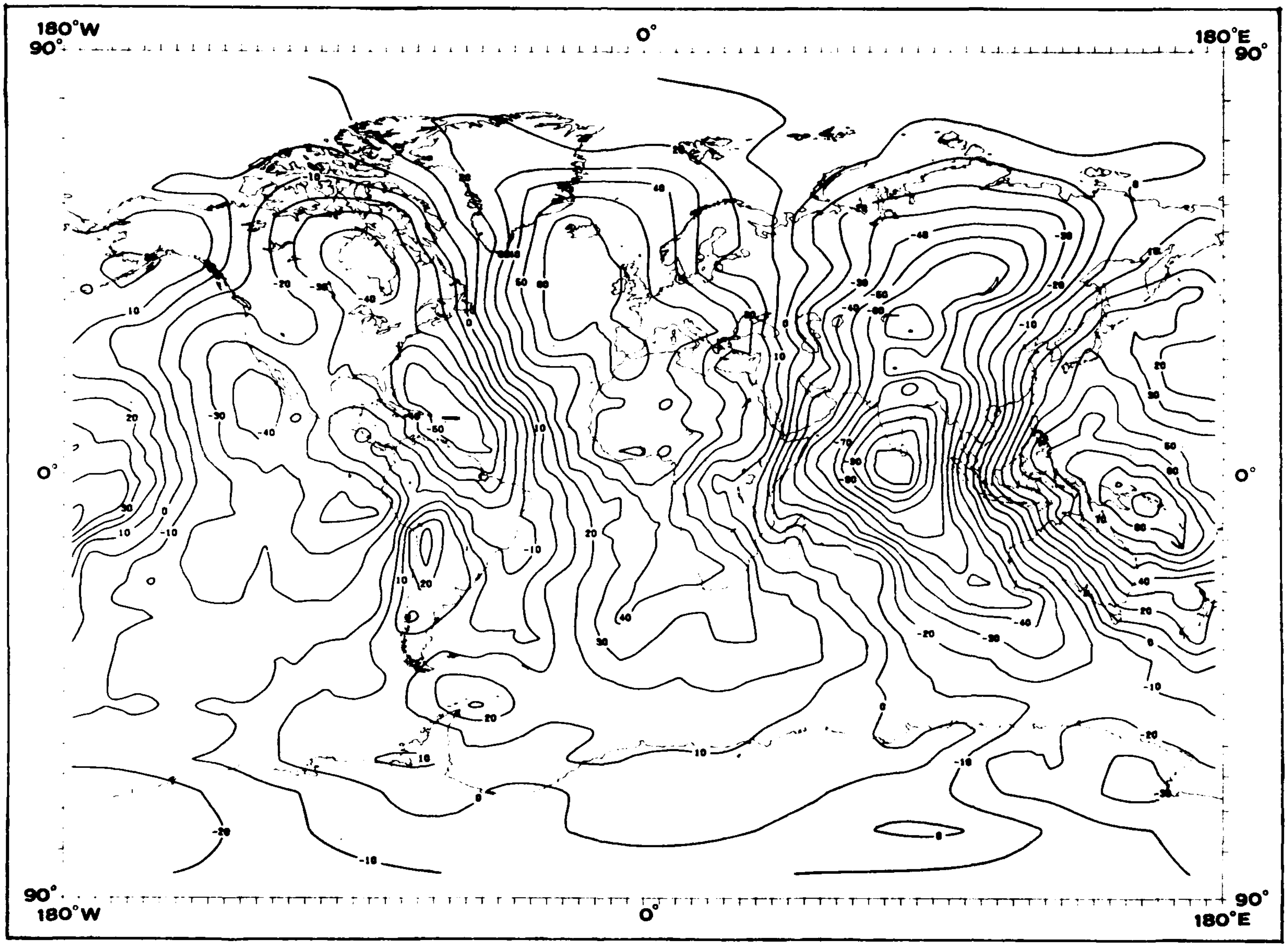
This result is in good agreement with the GRS 67 adopted value and represents a flattening of 1/298.2493 (See Appendix B).

The final set of harmonic coefficients (36,36) given in Appendix C was used to compute geoid heights worldwide (Figure 4). The geoid is referred to an ellipsoidal flattening of 1/298.2493 with contours at 10 meter intervals. A geoid-map covering the United States and Central Europe was constructed from the same set of harmonic coefficients with a one meter contour interval (Figures 5 & 6). All geoid heights were computed using the formulation

$$N = \sum_{n=2}^{36} \frac{R}{\gamma(n-1)} \sum_{m=0}^{n} (A_{nm} \cos m\lambda + B_{nm} \sin m\lambda)\, P_{nm}(\sin\phi)$$

The Degree Variances for HARMOGRAV are given in Appendix D.

GEOID MAP OF THE WORLD

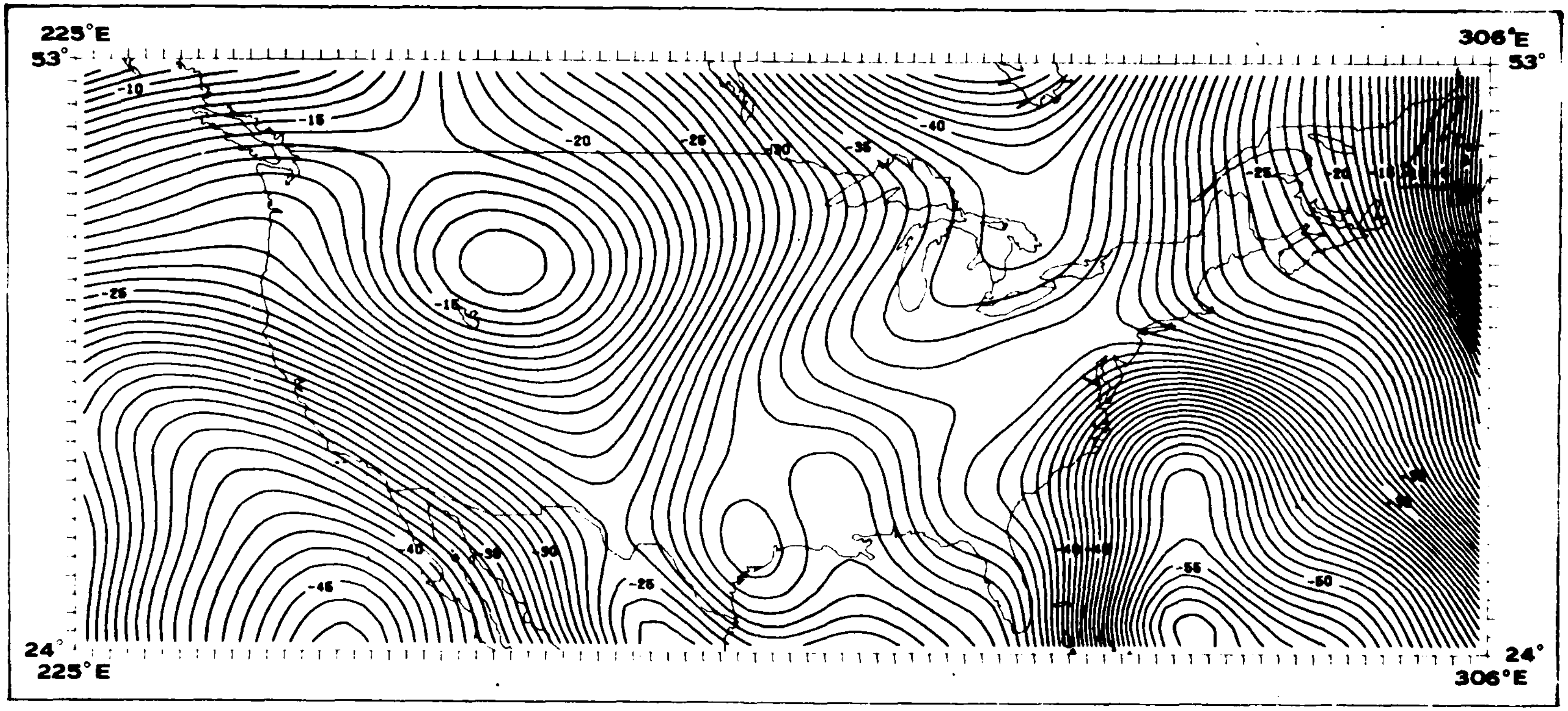


CONTOUR INTERVAL = 10 METERS

COMPUTED FROM THE HARMOGRAV GRAVITY MODEL

FIGURE 4

GEOID MAP OF THE UNITED STATES

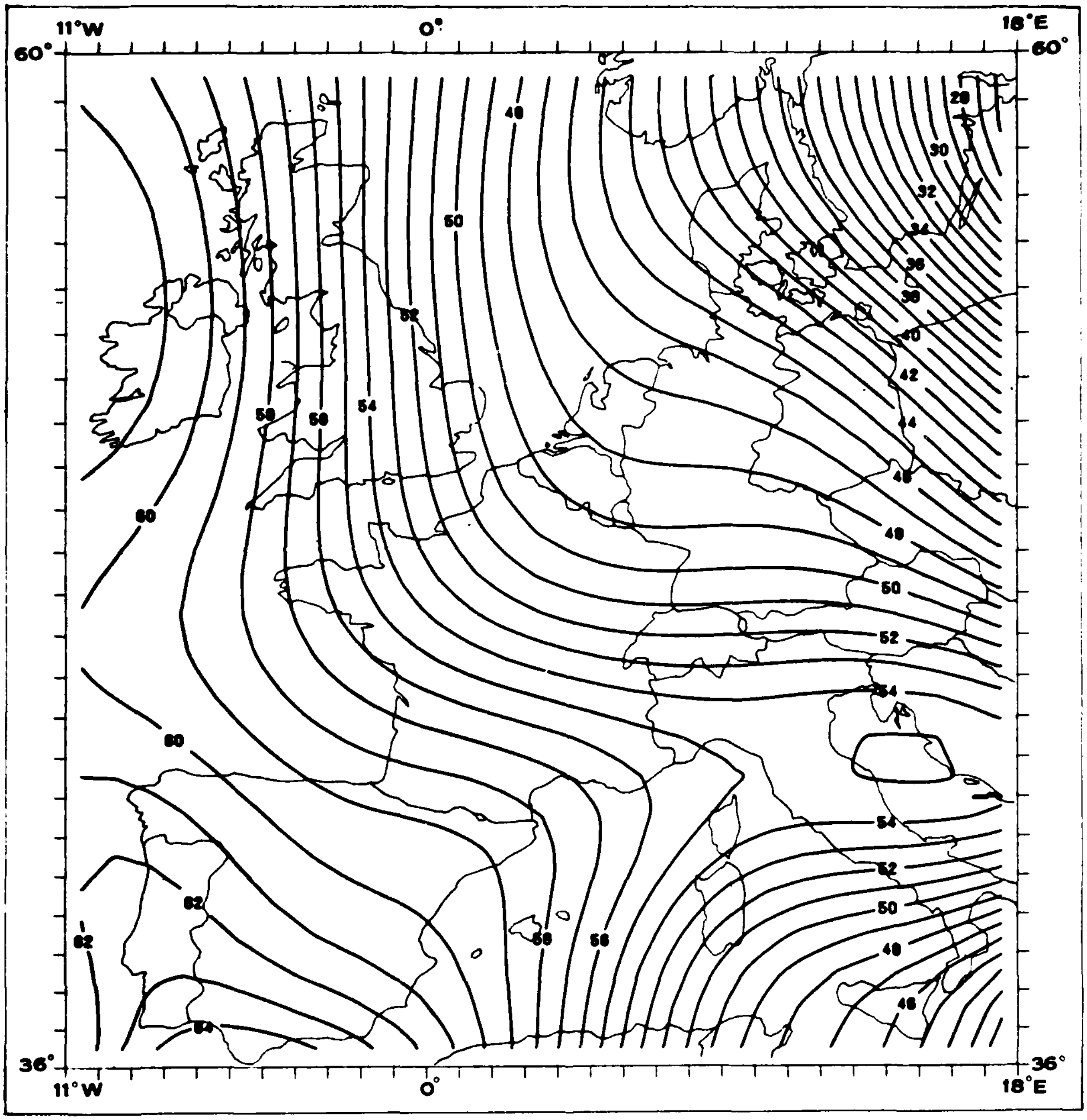


CONTOUR INTERVAL = 1 METER

COMPUTED FROM THE HARMOGRAV GRAVITY MODEL

FIGURE 5

GEOID MAP OF CENTRAL EUROPE



CONTOUR INTERVAL = 1 METER

COMPUTED FROM THE HARMOGRAV GRAVITY MODEL

FIGURE 6

VIII. CONCLUSIONS

This study demonstrates a new way to estimate a composite earth gravity model, representing 5° x 5° equal area gravity anomalies, by harmonic coefficients of the earth's gravity potential. This earth gravity model represents a pure terrestrial gravitational potential, developed by conventional mathematical formulas. It is understandable that this model is not final; however, no model can be final as long as the required observational data remains incomplete. As more data becomes available, the method outlined above, can be used to develop improved models.

In this study, it was decided that different weights should not be given to the starting values for the sector anomalies, since there was no apparent reason to do so. An equal weight system was used based on the requirement that every input 5° x 5° sector anomaly values shall be computed from a minimum of 20 per cent of the possible maximum number of 1° x 1° values distributed within the sectors.

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HARMOGRAV

Appendix A

Mean Free-Air Gravity Anomalies

APPENDIX A

HARMOGRAV MEAN FREE-AIR GRAVITY ANOMALIES

No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG
1	86.57	60.00	-4.	2	86.57	180.00	4.	3	86.57	300.00	12.	4	82.07	18.00	9.
5	82.07	54.00	5.	6	82.07	90.00	-4.	7	82.07	126.00	22.	8	82.07	162.00	1.
9	82.07	198.00	10.	10	82.07	234.00	6.	11	82.07	270.00	5.	12	82.07	306.00	28.
13	82.07	342.00	-14.	14	77.14	11.25	6.	15	77.14	33.75	-14.	16	77.14	56.25	8.
17	77.14	78.75	11.	18	77.14	101.25	-7.	19	77.14	123.75	10.	20	77.14	146.25	1.
21	77.14	168.75	-12.	22	77.14	191.25	5.	23	77.14	213.75	-2.	24	77.14	236.25	11.
25	77.14	258.75	-11.	26	77.14	281.25	10.	27	77.14	303.75	25.	28	77.14	326.25	-1.
29	77.14	348.75	-15.	30	72.33	8.57	33.	31	72.33	25.71	2.	32	72.33	42.86	16.
33	72.33	60.00	2.	34	72.33	77.14	-4.	35	72.33	94.29	-7.	36	72.33	111.43	1.
37	72.33	128.57	-1.	38	72.33	145.71	14.	39	72.33	162.86	0.	40	72.33	180.00	-2.
41	72.33	197.14	-1.	42	72.33	214.28	-22.	43	72.33	231.43	2.	44	72.33	248.57	-11.
45	72.33	265.71	-4.	46	72.33	282.86	-10.	47	72.33	300.00	5.	48	72.33	317.14	29.
49	72.33	334.28	33.	50	72.33	351.43	34.	51	67.44	6.43	17.	52	67.44	19.29	1.
53	67.44	32.14	13.	54	67.44	45.00	-6.	55	67.44	57.86	-25.	56	67.44	70.71	-27.
57	67.44	83.57	-4.	58	67.44	96.43	-4.	59	67.44	109.29	-9.	60	67.44	122.14	-32.
61	67.44	135.00	-30.	62	67.44	147.86	1.	63	67.44	160.71	0.	64	67.44	173.57	16.
65	67.44	186.43	-11.	66	67.44	199.29	2.	67	67.44	212.14	23.	68	67.44	225.00	19.
69	67.44	237.86	-3.	70	67.44	250.71	-24.	71	67.44	263.57	-34.	72	67.44	276.43	-55.
73	67.44	289.29	-23.	74	67.44	302.14	15.	75	67.44	315.00	-1.	76	67.44	327.86	39.
77	67.44	340.71	41.	78	67.44	353.57	21.	79	62.42	5.29	15.	80	62.42	15.88	-3.
81	62.42	26.47	-1.	82	62.42	37.06	15.	83	62.42	47.65	-13.	84	62.42	58.24	-7.
85	62.42	68.82	-12.	86	62.42	79.41	-15.	87	62.42	90.00	-20.	88	62.42	100.59	-32.
89	62.42	111.18	-35.	90	62.42	121.77	-34.	91	62.42	132.35	-22.	92	62.42	142.94	5.
93	62.42	153.53	10.	94	62.42	164.12	6.	95	62.42	174.71	11.	96	62.42	185.30	0.
97	62.42	195.88	7.	98	62.42	206.47	14.	99	62.42	217.06	37.	100	62.42	227.65	42.
101	62.42	238.24	-9.	102	62.42	248.83	-19.	103	62.42	259.41	-35.	104	62.42	270.00	-40.
105	62.42	280.59	-25.	106	62.42	291.18	-9.	107	62.42	301.77	-1.	108	62.42	312.35	-23.
109	62.42	322.94	17.	110	62.42	333.53	55.	111	62.42	344.12	26.	112	62.42	354.71	40.
113	57.42	4.62	2.	114	57.42	13.85	-2.	115	57.42	23.08	-30.	116	57.42	32.31	-4.
117	57.42	41.54	9.	118	57.42	50.77	27.	119	57.42	60.00	15.	120	57.42	69.23	10.
121	57.42	78.46	-6.	122	57.42	87.69	-25.	123	57.42	96.92	-42.	124	57.42	106.15	-50.
125	57.42	115.39	-49.	126	57.42	124.62	-28.	127	57.42	133.85	-9.	128	57.42	143.08	-3.
129	57.42	152.31	-2.	130	57.42	161.54	-5.	131	57.42	170.77	15.	132	57.42	180.00	-16.
133	57.42	189.23	14.	134	57.42	198.46	37.	135	57.42	207.69	17.	136	57.42	216.92	32.
137	57.42	226.15	15.	138	57.42	235.39	[illegible]	139	57.42	244.62	-4.	140	57.42	253.85	-17.
141	57.42	263.08	-28.	142	57.42	272.31	-35.	143	57.42	281.54	-35.	144	57.42	290.77	-26.
145	57.42	300.00	-19.	146	57.42	309.23	3.	147	57.42	318.46	21.	148	57.42	327.69	32.
149	57.42	336.92	18.	150	57.42	346.15	[illegible]	151	57.42	355.39	19.	152	52.46	4.09	-3.
153	52.46	12.27	13.	154	52.46	20.45	-1.	155	52.46	28.64	9.	156	52.46	36.82	9.
157	52.46	45.00	1.	158	52.46	53.18	5.	159	52.46	61.36	9.	160	52.46	69.55	42.
161	52.46	77.73	-12.	162	52.46	85.91	-25.	163	52.46	94.09	-23.	164	52.46	102.27	-43.
165	52.46	110.46	-47.	166	52.46	118.64	-35.	167	52.46	126.82	-7.	168	52.46	135.00	5.
169	52.46	143.18	10.	170	52.46	151.37	0.	171	52.46	159.55	9.	172	52.46	167.73	33.
173	52.46	175.91	31.	174	52.46	184.09	-35.	175	52.46	192.27	1.	176	52.46	200.46	22.
177	52.46	208.64	11.	178	52.46	216.82	5.	179	52.46	225.00	-3.	180	52.46	233.18	5.
181	52.46	241.37	11.	182	52.46	249.55	-1.	183	52.46	257.73	4.	184	52.46	265.91	-10.
185	52.46	274.09	-29.	186	52.46	282.28	-29.	187	52.46	290.46	-7.	188	52.46	298.64	-40.
189	52.46	306.82	-6.	190	52.46	315.00	39.	191	52.46	323.19	29.	192	52.46	331.37	49.
193	52.46	339.55	18.	194	52.46	347.73	16.	195	52.46	355.91	19.	196	47.48	3.67	1.
197	47.48	11.02	14.	198	47.48	18.37	21.	199	47.48	25.71	24.	200	47.48	33.06	23.
201	47.48	40.41	19.	202	47.48	47.75	-22.	203	47.48	55.10	-23.	204	47.48	62.45	-40.
205	47.48	69.80	-37.	206	47.48	77.14	-43.	207	47.48	84.49	-35.	208	47.48	91.84	-10.

No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG
209	47.48	99.18	11.	210	47.48	106.53	6.	211	47.48	113.88	7.	212	47.48	121.27	18.
213	47.48	128.57	14.	214	47.48	135.92	18.	215	47.48	143.26	30.	216	47.48	150.61	18.
217	47.48	157.96	20.	218	47.48	165.31	9.	219	47.48	172.65	7.	220	47.48	180.00	16.
221	47.48	187.35	8.	222	47.48	194.69	18.	223	47.48	202.04	10.	224	47.48	209.39	8.
225	47.48	216.73	-10.	226	47.48	224.08	-10.	227	47.48	231.43	-8.	228	47.48	238.77	-7.
229	47.48	246.12	10.	230	47.48	253.47	12.	231	47.48	260.81	9.	232	47.48	268.16	2.
233	47.48	275.51	-7.	234	47.48	282.86	-17.	235	47.48	290.20	-4.	236	47.48	297.55	-14.
237	47.48	304.90	7.	238	47.48	312.24	25.	239	47.48	319.59	19.	240	47.48	326.94	27.
241	47.48	334.28	35.	242	47.48	341.63	14.	243	47.48	348.98	7.	244	47.48	356.33	4.
245	42.47	3.33	15.	246	42.47	10.00	12.	247	42.47	16.67	28.	248	42.47	23.33	36.
249	42.47	30.00	29.	250	42.47	36.67	-4.	251	42.47	43.33	-9.	252	42.47	50.00	-17.
253	42.47	56.67	-23.	254	42.47	63.33	-20.	255	42.47	70.00	-23.	256	42.47	76.67	-44.
257	42.47	83.33	-61.	258	42.47	90.00	-47.	259	42.47	96.67	-7.	260	42.47	103.33	6.
261	42.47	110.00	-9.	262	42.47	116.67	-6.	263	42.47	123.33	-6.	264	42.47	130.00	-12.
265	42.47	136.67	5.	266	42.47	143.33	32.	267	42.47	150.00	7.	268	42.47	156.67	7.
269	42.47	163.33	26.	270	42.47	170.00	15.	271	42.47	176.67	13.	272	42.47	183.33	3.
273	42.47	190.00	-10.	274	42.47	196.67	-25.	275	42.47	203.33	-7.	276	42.47	210.00	-7.
277	42.47	216.67	-10.	278	42.47	223.33	-11.	279	42.47	230.00	-5.	280	42.47	236.67	0.
281	42.47	243.33	14.	282	42.47	250.00	26.	283	42.47	256.67	10.	284	42.47	263.33	0.
285	42.47	270.00	-12.	286	42.47	276.67	-12.	287	42.47	283.33	-4.	288	42.47	290.00	8.
289	42.47	296.67	-12.	290	42.47	303.33	-15.	291	42.47	310.00	10.	292	42.47	316.67	6.
293	42.47	323.33	8.	294	42.47	330.00	30.	295	42.47	336.67	28.	296	42.47	343.33	7.
297	42.47	350.00	17.	298	42.47	356.67	10.	299	37.47	3.16	13.	300	37.47	9.47	-1.
301	37.47	15.79	5.	302	37.47	22.11	-16.	303	37.47	28.42	2.	304	37.47	34.74	27.
305	37.47	41.05	17.	306	37.47	47.37	26.	307	37.47	53.69	21.	308	37.47	60.00	-17.
309	37.47	66.32	-12.	310	37.47	72.63	-19.	311	37.47	78.95	20.	312	37.47	85.26	-11.
313	37.47	91.58	-8.	314	37.47	97.90	2.	315	37.47	104.21	6.	316	37.47	110.53	9.
317	37.47	116.84	11.	318	37.47	123.16	16.	319	37.47	129.48	17.	320	37.47	135.79	33.
321	37.47	142.11	15.	322	37.47	148.42	-3.	323	37.47	154.74	0.	324	37.47	161.06	-19.
325	37.47	167.37	-22.	326	37.47	173.69	0.	327	37.47	180.00	-11.	328	37.47	186.32	-11.
329	37.47	192.64	-12.	330	37.47	198.95	-5.	331	37.47	205.27	5.	332	37.47	211.58	-7.
333	37.47	217.90	-14.	334	37.47	224.21	-19.	335	37.47	230.53	-22.	336	37.47	236.85	-11.
337	37.47	243.16	0.	338	37.47	249.48	9.	339	37.47	255.79	9.	340	37.47	262.11	-6.
341	37.47	268.43	-6.	342	37.47	274.74	-1.	343	37.47	281.06	4.	344	37.47	287.37	-25.
345	37.47	293.69	-15.	346	37.47	300.01	-17.	347	37.47	306.32	-12.	348	37.47	312.64	-2.
349	37.47	318.95	20.	350	37.47	325.27	33.	351	37.47	331.58	37.	352	37.47	337.90	15.
353	37.47	344.22	-3.	354	37.47	350.53	16.	355	37.47	356.85	11.	356	32.50	2.95	7.
357	32.50	8.85	-5.	358	32.50	14.75	5.	359	32.50	20.66	-8.	360	32.50	26.56	-38.
361	32.50	32.46	11.	362	32.50	38.36	27.	363	32.50	44.26	-10.	364	32.50	50.16	6.
365	32.50	56.07	30.	366	32.50	61.97	23.	367	32.50	67.87	-21.	368	32.50	73.77	-13.
369	32.50	79.67	61.	370	32.50	85.57	12.	371	32.50	91.48	21.	372	32.50	97.38	5.
373	32.50	103.28	12.	374	32.50	109.18	11.	375	32.50	115.08	3.	376	32.50	120.98	22.
377	32.50	126.89	14.	378	32.50	132.79	13.	379	32.50	138.69	32.	380	32.50	144.59	-7.
381	32.50	150.49	-4.	382	32.50	156.40	-3.	383	32.50	162.30	-17.	384	32.50	168.20	-18.
385	32.50	174.10	-7.	386	32.50	180.00	-8.	387	32.50	185.90	-10.	388	32.50	191.81	-15.
389	32.50	197.71	-13.	390	32.50	203.61	-12.	391	32.50	209.51	-4.	392	32.50	215.41	-17.
393	32.50	221.31	-13.	394	32.50	227.22	-6.	395	32.50	233.12	-17.	396	32.50	239.02	-16.
397	32.50	244.92	-7.	398	32.50	250.82	2.	399	32.50	256.72	6.	400	32.50	262.63	-9.
401	32.50	268.53	7.	402	32.50	274.43	-6.	403	32.50	280.33	-2.	404	32.50	286.23	-33.
405	32.50	292.13	-27.	406	32.50	298.04	-12.	407	32.50	303.94	-5.	408	32.50	309.84	1.
409	32.50	315.74	14.	410	32.50	321.64	28.	411	32.50	327.54	17.	412	32.50	333.45	-6.
413	32.50	339.35	-17.	414	32.50	345.25	-3.	415	32.50	351.15	37.	416	32.50	357.05	39.
417	27.47	2.77	-13.	418	27.47	8.31	5.	419	27.47	13.85	-6.	420	27.47	19.38	7.
421	27.47	24.92	7.	422	27.47	30.46	8.	423	27.47	36.00	9.	424	27.47	41.54	10.
425	27.47	47.08	-7.	426	27.47	52.61	-12.	427	27.47	58.15	7.	428	27.47	63.69	19.
429	27.47	69.23	-5.	430	27.47	74.77	-30.	431	27.47	80.31	-54.	432	27.47	85.84	-80.
433	27.47	91.38	-14.	434	27.47	96.92	-38.	435	27.47	102.46	-25.	436	27.47	108.00	-6.

No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG
437	27.47	113.54	10.	438	27.47	119.07	19.	439	27.47	124.61	21.	440	27.47	130.16	4.
441	27.47	135.69	14.	442	27.47	141.23	21.	443	27.47	146.76	15.	444	27.47	152.30	14.
445	27.47	157.84	-12.	446	27.47	163.38	-16.	447	27.47	168.92	-18.	448	27.47	174.46	-16.
449	27.47	179.99	-10.	450	27.47	185.53	-6.	451	27.47	191.07	3.	452	27.47	196.61	9.
453	27.47	202.15	4.	454	27.47	207.69	-4.	455	27.47	213.22	-1.	456	27.47	218.76	0.
457	27.47	224.30	-5.	458	27.47	229.84	-15.	459	27.47	235.38	-15.	460	27.47	240.92	-22.
461	27.47	246.45	-13.	462	27.47	251.99	1.	463	27.47	257.53	16.	464	27.47	263.07	-13.
465	27.47	268.61	-1.	466	27.47	274.15	0.	467	27.47	279.68	9.	468	27.47	285.22	-31.
469	27.47	290.76	-31.	470	27.47	296.30	-19.	471	27.47	301.84	-30.	472	27.47	307.38	-18.
473	27.47	312.91	10.	474	27.47	318.45	14.	475	27.47	323.99	3.	476	27.47	329.53	9.
477	27.47	335.07	-11.	478	27.47	340.61	-2.	479	27.47	346.14	3.	480	27.47	351.68	9.
481	27.47	357.22	4.	482	22.47	2.73	19.	483	22.47	8.18	38.	484	22.47	13.64	12.
485	22.47	19.09	13.	486	22.47	24.55	21.	487	22.47	30.00	19.	488	22.47	35.46	8.
489	22.47	40.91	31.	490	22.47	46.36	7.	491	22.47	51.82	-32.	492	22.47	57.27	14.
493	22.47	62.73	4.	494	22.47	68.18	1.	495	22.47	73.64	2.	496	22.47	79.09	4.
497	22.47	84.55	1.	498	22.47	90.00	-10.	499	22.47	95.46	-30.	500	22.47	100.91	-18.
501	22.47	106.37	-17.	502	22.47	111.82	-9.	503	22.47	117.28	-4.	504	22.47	122.73	5.
505	22.47	128.19	2.	506	22.47	133.64	1.	507	22.47	139.09	24.	508	22.47	144.55	13.
509	22.47	150.00	8.	510	22.47	155.46	13.	511	22.47	160.91	-17.	512	22.47	166.37	-13.
513	22.47	171.82	-3.	514	22.47	177.28	-5.	515	22.47	182.73	-5.	516	22.47	188.19	8.
517	22.47	193.64	10.	518	22.47	199.10	15.	519	22.47	204.55	24.	520	22.47	210.01	-1.
521	22.47	215.46	-6.	522	22.47	220.92	-5.	523	22.47	226.37	-8.	524	22.47	231.82	-13.
525	22.47	237.28	-21.	526	22.47	242.73	-21.	527	22.47	248.19	-7.	528	22.47	253.64	-6.
529	22.47	259.10	22.	530	22.47	264.55	4.	531	22.47	270.01	7.	532	22.47	275.46	-1.
533	22.47	280.92	-2.	534	22.47	286.37	-35.	535	22.47	291.83	-33.	536	22.47	297.28	-28.
537	22.47	302.74	-18.	538	22.47	308.19	-19.	539	22.47	313.65	4.	540	22.47	319.10	-7.
541	22.47	324.55	3.	542	22.47	330.01	4.	543	22.47	335.46	2.	544	22.47	340.92	9.
545	22.47	346.37	4.	546	22.47	351.83	-15.	547	22.47	357.28	-2.	548	17.49	2.61	9.
549	17.49	7.63	7.	550	17.49	13.04	-7.	551	17.49	18.26	-1.	552	17.49	23.48	3.
553	17.49	28.70	1.	554	17.49	33.91	12.	555	17.49	39.13	24.	556	17.49	44.35	8.
557	17.49	49.57	-25.	558	17.49	54.78	7.	559	17.49	60.00	18.	560	17.49	65.22	-11.
561	17.49	70.44	-26.	562	17.49	75.65	-21.	563	17.49	80.87	-16.	564	17.49	86.09	-42.
565	17.49	91.31	-24.	566	17.49	96.52	-6.	567	17.49	101.74	-14.	568	17.49	106.96	-18.
569	17.49	112.18	-15.	570	17.49	117.39	2.	571	17.49	122.61	30.	572	17.49	127.83	9.
573	17.49	133.05	7.	574	17.49	138.26	30.	575	17.49	143.48	23.	576	17.49	148.70	-14.
577	17.49	153.92	-10.	578	17.49	159.13	-7.	579	17.49	164.35	-1.	580	17.49	169.57	-3.
581	17.49	174.79	-9.	582	17.49	180.00	1.	583	17.49	185.22	1.	584	17.49	190.44	-5.
585	17.49	195.66	1.	586	17.49	200.87	12.	587	17.49	206.09	20.	588	17.49	211.31	1.
589	17.49	216.53	-8.	590	17.49	221.74	-12.	591	17.49	226.96	3.	592	17.49	232.18	-12.
593	17.49	237.40	-15.	594	17.49	242.61	-19.	595	17.49	247.83	0.	596	17.49	253.05	-34.
597	17.49	258.27	-10.	598	17.49	263.48	15.	599	17.49	268.70	25.	600	17.49	273.92	16.
601	17.49	279.14	6.	602	17.49	284.35	22.	603	17.49	289.57	16.	604	17.49	294.79	-28.
605	17.49	300.01	-43.	606	17.49	305.22	-43.	607	17.49	310.44	-29.	608	17.49	315.66	-24.
609	17.49	320.88	-32.	610	17.49	326.09	0.	611	17.49	331.31	13.	612	17.49	336.53	39.
613	17.49	341.75	14.	614	17.49	346.96	14.	615	17.49	352.18	6.	616	17.49	357.40	10.
617	12.51	2.57	0.	618	12.51	7.71	15.	619	12.51	12.86	11.	620	12.51	18.00	33.
621	12.51	23.14	27.	622	12.51	28.29	13.	623	12.51	33.43	23.	624	12.51	38.57	24.
625	12.51	43.71	12.	626	12.51	48.86	11.	627	12.51	54.00	-5.	628	12.51	59.14	-4.
629	12.51	64.28	-1.	630	12.51	69.43	-24.	631	12.51	74.57	-29.	632	12.51	79.71	-27.
633	12.51	84.86	-49.	634	12.51	90.00	-14.	635	12.51	95.14	-5.	636	12.51	100.28	-9.
637	12.51	105.43	-4.	638	12.51	110.57	0.	639	12.51	115.71	7.	640	12.51	120.86	29.
641	12.51	126.00	22.	642	12.51	131.14	10.	643	12.51	136.28	7.	644	12.51	141.43	-12.
645	12.51	146.57	-11.	646	12.51	151.71	-2.	647	12.51	156.86	0.	648	12.51	162.00	-3.
649	12.51	167.14	-1.	650	12.51	172.28	4.	651	12.51	177.43	16.	652	12.51	182.57	8.
653	12.51	187.71	7.	654	12.51	192.85	-2.	655	12.51	198.00	8.	656	12.51	203.14	-8.
657	12.51	208.28	-7.	658	12.51	213.43	0.	659	12.51	218.57	1.	660	12.51	223.71	-10.
661	12.51	228.85	-10.	662	12.51	234.00	-16.	663	12.51	239.14	-10.	664	12.51	244.28	-18.

No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG
665	12.51	249.43	12.	666	12.51	254.57	-7.	667	12.51	259.71	14.	668	12.51	264.86	9.
669	12.51	270.00	29.	670	12.51	275.14	31.	671	12.51	280.28	6.	672	12.51	285.43	-24.
673	12.51	290.57	-23.	674	12.51	295.71	-23.	675	12.51	300.85	-27.	676	12.51	306.00	-32.
677	12.51	311.14	-36.	678	12.51	316.28	-12.	679	12.51	321.42	-26.	680	12.51	326.57	-11.
681	12.51	331.71	-3.	682	12.51	336.85	8.	683	12.51	342.00	2.	684	12.51	347.14	16.
685	12.51	352.28	8.	686	12.51	357.42	6.	687	7.51	2.50	17.	688	7.51	7.50	32.
689	7.51	12.50	14.	690	7.51	17.50	6.	691	7.51	22.50	-6.	692	7.51	27.50	10.
693	7.51	32.50	26.	694	7.51	37.50	26.	695	7.51	42.50	4.	696	7.51	47.50	-21.
697	7.51	52.50	-43.	698	7.51	57.50	-9.	699	7.51	62.50	-20.	700	7.51	67.50	-36.
701	7.51	72.50	-46.	702	7.51	77.50	-31.	703	7.51	82.50	-37.	704	7.51	87.50	-21.
705	7.51	92.50	-19.	706	7.51	97.50	6.	707	7.51	102.50	10.	708	7.51	107.50	4.
709	7.51	112.50	8.	710	7.51	117.50	34.	711	7.51	122.50	52.	712	7.51	127.50	21.
713	7.51	132.50	21.	714	7.51	137.50	21.	715	7.51	142.50	17.	716	7.51	147.50	13.
717	7.51	152.50	2.	718	7.51	157.50	13.	719	7.51	162.50	5.	720	7.51	167.50	3.
721	7.51	172.50	13.	722	7.51	177.50	5.	723	7.51	182.50	-26.	724	7.51	187.50	-8.
725	7.51	192.50	6.	726	7.51	197.50	35.	727	7.51	202.50	9.	728	7.51	207.50	14.
729	7.51	212.50	-2.	730	7.51	217.50	8.	731	7.51	222.50	-11.	732	7.51	227.50	-10.
733	7.51	232.50	-20.	734	7.51	237.50	-4.	735	7.51	242.50	-13.	736	7.51	247.50	-2.
737	7.51	252.50	-6.	738	7.51	257.50	7.	739	7.51	262.50	4.	740	7.51	267.50	12.
741	7.51	272.50	19.	742	7.51	277.50	28.	743	7.51	282.50	34.	744	7.51	287.50	12.
745	7.51	292.50	12.	746	7.51	297.50	-13.	747	7.51	302.50	-22.	748	7.51	307.50	-29.
749	7.51	312.50	-50.	750	7.51	317.50	-1.	751	7.51	322.50	-9.	752	7.51	327.50	13.
753	7.51	332.50	0.	754	7.51	337.50	12.	755	7.51	342.50	27.	756	7.51	347.50	37.
757	7.51	352.50	29.	758	7.51	357.50	22.	759	2.50	2.50	20.	760	2.50	7.50	22.
761	2.50	12.50	27.	762	2.50	17.50	-10.	763	2.50	22.50	-37.	764	2.50	27.50	3.
765	2.50	32.50	0.	766	2.50	37.50	6.	767	2.50	42.50	-10.	768	2.50	47.50	-21.
769	2.50	52.50	-34.	770	2.50	57.50	-12.	771	2.50	62.50	-39.	772	2.50	67.50	-31.
773	2.50	72.50	-49.	774	2.50	77.50	-55.	775	2.50	82.50	-61.	776	2.50	87.50	-23.
777	2.50	92.50	-11.	778	2.50	97.50	19.	779	2.50	102.50	9.	780	2.50	107.50	27.
781	2.50	112.50	33.	782	2.50	117.50	36.	783	2.50	122.50	31.	784	2.50	127.50	20.
785	2.50	132.50	57.	786	2.50	137.50	31.	787	2.50	142.50	19.	788	2.50	147.50	25.
789	2.50	152.50	-5.	790	2.50	157.50	12.	791	2.50	162.50	8.	792	2.50	167.50	-7.
793	2.50	172.50	-17.	794	2.50	177.50	8.	795	2.50	182.50	6.	796	2.50	187.50	2.
797	2.50	192.50	0.	798	2.50	197.50	22.	799	2.50	202.50	-13.	800	2.50	207.50	12.
801	2.50	212.50	-6.	802	2.50	217.50	8.	803	2.50	222.50	-7.	804	2.50	227.50	-3.
805	2.50	232.50	-2.	806	2.50	237.50	3.	807	2.50	242.50	[illegible]	808	2.50	247.50	3.
809	2.50	252.50	-7.	810	2.50	257.50	-6.	811	2.50	262.50	-5.	812	2.50	267.50	4.
813	2.50	272.50	0.	814	2.50	277.50	5.	815	2.50	282.50	29.	816	2.50	287.50	31.
817	2.50	292.50	1.	818	2.50	297.50	-19.	819	2.50	302.50	[illegible]	820	2.50	307.50	-13.
821	2.50	312.50	-39.	822	2.50	317.50	-15.	823	2.50	322.50	[illegible]	824	2.50	327.50	14.
825	2.50	332.50	7.	826	2.50	337.50	27.	827	2.50	342.50	-4.	828	2.50	347.50	-5.
829	2.50	352.50	1.	830	2.50	357.50	21.	831	-2.50	2.50	19.	832	-2.50	7.50	-12.
833	-2.50	12.50	-14.	834	-2.50	17.50	-21.	835	-2.50	22.50	-36.	836	-2.50	27.50	0.
837	-2.50	32.50	0.	838	-2.50	37.50	12.	839	-2.50	42.50	-36.	840	-2.50	47.50	-21.
841	-2.50	52.50	-10.	842	-2.50	57.50	-10.	843	-2.50	62.50	-24.	844	-2.50	67.50	-25.
845	-2.50	72.50	-50.	846	-2.50	77.50	-45.	847	-2.50	82.50	-58.	848	-2.50	87.50	-28.
849	-2.50	92.50	-23.	850	-2.50	97.50	11.	851	-2.50	102.50	16.	852	-2.50	107.50	41.
853	-2.50	112.50	34.	854	-2.50	117.50	25.	855	-2.50	122.50	1.	856	-2.50	127.50	5.
857	-2.50	132.50	21.	858	-2.50	137.50	7.	859	-2.50	142.50	26.	860	-2.50	147.50	45.
861	-2.50	152.50	27.	862	-2.50	157.50	30.	863	-2.50	162.50	19.	864	-2.50	167.50	-18.
865	-2.50	172.50	-27.	866	-2.50	177.50	-7.	867	-2.50	182.50	-9.	868	-2.50	187.50	6.
869	-2.50	192.50	6.	870	-2.50	197.50	39.	871	-2.50	202.50	16.	872	-2.50	207.50	29.
873	-2.50	212.50	7.	874	-2.50	217.50	8.	875	-2.50	222.50	-1.	876	-2.50	227.50	8.
877	-2.50	232.50	6.	878	-2.50	237.50	3.	879	-2.50	242.50	-7.	880	-2.50	247.50	8.
881	-2.50	252.50	6.	882	-2.50	257.50	-10.	883	-2.50	262.50	-15.	884	-2.50	267.50	-29.
885	-2.50	272.50	-13.	886	-2.50	277.50	-10.	887	-2.50	282.50	10.	888	-2.50	287.50	48.
889	-2.50	292.50	4.	890	-2.50	297.50	0.	891	-2.50	302.50	-12.	892	-2.50	307.50	5.

No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG
893	-2.50	312.50	-29.	894	-2.50	317.50	-23.	895	-2.50	322.50	3.	896	-2.50	327.50	4.
897	-2.50	332.50	-20.	898	-2.50	337.50	-6.	899	-2.50	342.50	-3.	900	-2.50	347.50	14.
901	-2.50	352.50	-8.	902	-2.50	357.50	19.	903	-7.51	2.50	12.	904	-7.51	7.50	19.
905	-7.51	12.50	-5.	906	-7.51	17.50	9.	907	-7.51	22.50	-17.	908	-7.51	27.50	-3.
909	-7.51	32.50	4.	910	-7.51	37.50	13.	911	-7.51	42.50	-36.	912	-7.51	47.50	-19.
913	-7.51	52.50	-10.	914	-7.51	57.50	-4.	915	-7.51	62.50	-9.	916	-7.51	67.50	-8.
917	-7.51	72.50	-12.	918	-7.51	77.50	-28.	919	-7.51	82.50	-18.	920	-7.51	87.50	-9.
921	-7.51	92.50	-24.	922	-7.51	97.50	8.	923	-7.51	102.50	-14.	924	-7.51	107.50	15.
925	-7.51	112.50	19.	926	-7.51	117.50	11.	927	-7.51	122.50	-12.	928	-7.51	127.50	-13.
929	-7.51	132.50	-29.	930	-7.51	137.50	17.	931	-7.51	142.50	38.	932	-7.51	147.50	11.
933	-7.51	152.50	31.	934	-7.51	157.50	44.	935	-7.51	162.50	42.	936	-7.51	167.50	17.
937	-7.51	172.50	4.	938	-7.51	177.50	-2.	939	-7.51	182.50	-6.	940	-7.51	187.50	21.
941	-7.51	192.50	27.	942	-7.51	197.50	47.	943	-7.51	202.50	5.	944	-7.51	207.50	1.
945	-7.51	212.50	-2.	946	-7.51	217.50	-4.	947	-7.51	222.50	-4.	948	-7.51	227.50	3.
949	-7.51	232.50	-2.	950	-7.51	237.50	3.	951	-7.51	242.50	0.	952	-7.51	247.50	5.
953	-7.51	252.50	11.	954	-7.51	257.50	3.	955	-7.51	262.50	-8.	956	-7.51	267.50	-12.
957	-7.51	272.50	-1.	958	-7.51	277.50	-33.	959	-7.51	282.50	-33.	960	-7.51	287.50	2.
961	-7.51	292.50	-1.	962	-7.51	297.50	22.	963	-7.51	302.50	-22.	964	-7.51	307.50	-3.
965	-7.51	312.50	-29.	966	-7.51	317.50	-25.	967	-7.51	322.50	4.	968	-7.51	327.50	-16.
969	-7.51	332.50	-11.	970	-7.51	337.50	-8.	971	-7.51	342.50	-1.	972	-7.51	347.50	8.
973	-7.51	352.50	-19.	974	-7.51	357.50	-8.	975	-12.51	2.57	7.	976	-12.51	7.71	4.
977	-12.51	12.86	-12.	978	-12.51	18.00	2.	979	-12.51	23.14	-25.	980	-12.51	28.29	-7.
981	-12.51	33.43	-4.	982	-12.51	38.57	-21.	983	-12.51	43.71	-24.	984	-12.51	48.86	14.
985	-12.51	54.00	-3.	986	-12.51	59.14	25.	987	-12.51	64.28	6.	988	-12.51	69.43	6.
989	-12.51	74.57	-17.	990	-12.51	79.71	-22.	991	-12.51	84.86	12.	992	-12.51	90.00	-33.
993	-12.51	95.14	-7.	994	-12.51	100.28	-8.	995	-12.51	105.43	7.	996	-12.51	110.57	0.
997	-12.51	115.71	-22.	998	-12.51	120.86	1.	999	-12.51	126.00	25.	1000	-12.51	131.14	34.
1001	-12.51	136.28	24.	1002	-12.51	141.43	30.	1003	-12.51	146.57	13.	1004	-12.51	151.71	38.
1005	-12.51	156.86	33.	1006	-12.51	162.00	35.	1007	-12.51	167.14	41.	1008	-12.51	172.28	14.
1009	-12.51	177.43	-3.	1010	-12.51	182.57	19.	1011	-12.51	187.71	25.	1012	-12.51	192.85	19.
1013	-12.51	198.00	29.	1014	-12.51	203.14	0.	1015	-12.51	208.28	6.	1016	-12.51	213.43	-5.
1017	-12.51	218.57	-8.	1018	-12.51	223.71	-2.	1019	-12.51	228.85	3.	1020	-12.51	234.00	7.
1021	-12.51	239.14	4.	1022	-12.51	244.28	-1.	1023	-12.51	249.43	2.	1024	-12.51	254.57	-4.
1025	-12.51	259.71	-20.	1026	-12.51	264.85	-26.	1027	-12.51	270.00	-23.	1028	-12.51	275.14	-33.
1029	-12.51	280.28	-40.	1030	-12.51	285.43	-2.	1031	-12.51	290.57	13.	1032	-12.51	295.71	51.
1033	-12.51	300.85	22.	1034	-12.51	306.00	-4.	1035	-12.51	311.14	8.	1036	-12.51	316.28	-3.
1037	-12.51	321.42	9.	1038	-12.51	326.57	-11.	1039	-12.51	331.71	-2.	1040	-12.51	336.85	4.
1041	-12.51	342.00	-8.	1042	-12.51	347.14	0.	1043	-12.51	352.28	-6.	1044	-12.51	357.42	3.
1045	-17.49	2.61	8.	1046	-17.49	7.83	12.	1047	-17.49	13.04	20.	1048	-17.49	18.26	14.
1049	-17.49	23.48	5.	1050	-17.49	28.70	13.	1051	-17.49	33.91	1.	1052	-17.49	39.13	-31.
1053	-17.49	44.35	3.	1054	-17.49	49.57	30.	1055	-17.49	54.78	-10.	1056	-17.49	60.00	21.
1057	-17.49	65.22	-12.	1058	-17.49	70.44	-14.	1059	-17.49	75.65	-16.	1060	-17.49	80.87	-33.
1061	-17.49	86.09	-33.	1062	-17.49	91.31	-33.	1063	-17.49	96.52	-23.	1064	-17.49	101.74	-21.
1065	-17.49	106.96	6.	1066	-17.49	112.18	-28.	1067	-17.49	117.39	-1.	1068	-17.49	122.61	11.
1069	-17.49	127.83	15.	1070	-17.49	133.05	6.	1071	-17.49	138.26	8.	1072	-17.49	143.48	21.
1073	-17.49	148.70	20.	1074	-17.49	153.92	13.	1075	-17.49	159.13	10.	1076	-17.49	164.35	19.
1077	-17.49	169.56	30.	1078	-17.49	174.79	33.	1079	-17.49	180.00	42.	1080	-17.49	185.22	25.
1081	-17.49	190.44	-10.	1082	-17.49	195.66	-9.	1083	-17.49	200.87	-5.	1084	-17.49	206.09	3.
1085	-17.49	211.31	-3.	1086	-17.49	216.53	-18.	1087	-17.49	221.74	-14.	1088	-17.49	226.96	-11.
1089	-17.49	232.18	-13.	1090	-17.49	237.40	-7.	1091	-17.49	242.61	2.	1092	-17.49	247.83	1.
1093	-17.49	253.05	-16.	1094	-17.49	258.27	-19.	1095	-17.49	263.48	0.	1096	-17.49	268.70	-13.
1097	-17.49	273.92	-13.	1098	-17.49	279.14	-12.	1099	-17.49	284.35	14.	1100	-17.49	289.57	76.
1101	-17.49	294.79	43.	1102	-17.49	300.01	23.	1103	-17.49	305.22	-11.	1104	-17.49	310.44	-27.
1105	-17.49	315.66	-20.	1106	-17.49	320.88	-26.	1107	-17.49	326.09	-12.	1108	-17.49	331.31	-8.
1109	-17.49	336.53	-5.	1110	-17.49	341.75	-8.	1111	-17.49	346.96	22.	1112	-17.49	352.18	2.
1113	-17.49	357.40	-4.	1114	-22.47	2.73	3.	1115	-22.47	8.18	10.	1116	-22.47	13.64	16.
1117	-22.47	19.09	0.	1118	-22.47	24.55	2.	1119	-22.47	30.00	6.	1120	-22.47	35.46	-2.

No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG
1121	-22.47	40.91	-6.	1122	-22.47	46.36	31.	1123	-22.47	51.82	-5.	1124	-22.47	57.27	8.
1125	-22.47	62.73	36.	1126	-22.47	68.18	22.	1127	-22.47	73.64	28.	1128	-22.47	79.09	0.
1129	-22.47	84.55	-21.	1130	-22.47	90.00	-10.	1131	-22.47	95.46	-20.	1132	-22.47	100.91	-32.
1133	-22.47	106.37	-13.	1134	-22.47	111.82	-5.	1135	-22.47	117.28	10.	1136	-22.47	122.73	-2.
1137	-22.47	128.19	-3.	1138	-22.47	133.64	-1.	1139	-22.47	139.09	17.	1140	-22.47	144.55	10.
1141	-22.47	150.00	26.	1142	-22.47	155.46	7.	1143	-22.47	160.91	28.	1144	-22.47	166.37	61.
1145	-22.47	171.82	36.	1146	-22.47	177.28	25.	1147	-22.47	182.73	-33.	1148	-22.47	188.19	-58.
1149	-22.47	193.64	-8.	1150	-22.47	199.10	1.	1151	-22.47	204.55	-5.	1152	-22.47	210.01	-2.
1153	-22.47	215.46	-6.	1154	-22.47	220.92	-14.	1155	-22.47	226.37	-3.	1156	-22.47	231.82	-7.
1157	-22.47	237.28	-1.	1158	-22.47	242.73	11.	1159	-22.47	248.19	5.	1160	-22.47	253.64	-2.
1161	-22.47	259.10	-17.	1162	-22.47	264.55	-4.	1163	-22.47	270.01	-8.	1164	-22.47	275.46	14.
1165	-22.47	280.92	-24.	1166	-22.47	286.37	15.	1167	-22.47	291.83	70.	1168	-22.47	297.28	9.
1169	-22.47	302.74	29.	1170	-22.47	308.19	-15.	1171	-22.47	313.65	0.	1172	-22.47	319.10	-9.
1173	-22.47	324.55	-21.	1174	-22.47	330.01	-19.	1175	-22.47	335.46	-4.	1176	-22.47	340.92	-17.
1177	-22.47	346.37	2.	1178	-22.47	351.83	9.	1179	-22.47	357.28	-1.	1180	-27.47	2.77	10.
1181	-27.47	8.31	11.	1182	-27.47	13.85	26.	1183	-27.47	19.38	30.	1184	-27.47	24.92	23.
1185	-27.47	30.46	36.	1186	-27.47	36.00	-5.	1187	-27.47	41.54	-11.	1188	-27.47	47.08	11.
1189	-27.47	52.61	-11.	1190	-27.47	58.15	-1.	1191	-27.47	63.69	14.	1192	-27.47	69.23	41.
1193	-27.47	74.77	37.	1194	-27.47	80.31	8.	1195	-27.47	85.84	-5.	1196	-27.47	91.38	-11.
1197	-27.47	96.92	-27.	1198	-27.47	102.46	-17.	1199	-27.47	108.00	-35.	1200	-27.47	113.54	-8.
1201	-27.47	119.07	1.	1202	-27.47	124.61	-8.	1203	-27.47	130.15	-21.	1204	-27.47	135.69	-8.
1205	-27.47	141.23	-12.	1206	-27.47	146.76	3.	1207	-27.47	152.30	24.	1208	-27.47	157.84	-29.
1209	-27.47	163.38	19.	1210	-27.47	168.92	17.	1211	-27.47	174.46	26.	1212	-27.47	179.99	36.
1213	-27.47	185.53	-54.	1214	-27.47	191.07	-27.	1215	-27.47	196.61	-3.	1216	-27.47	202.15	-24.
1217	-27.47	207.69	-13.	1218	-27.47	213.22	-13.	1219	-27.47	218.76	-11.	1220	-27.47	224.30	-10.
1221	-27.47	229.84	-10.	1222	-27.47	235.38	-6.	1223	-27.47	240.92	7.	1224	-27.47	246.45	2.
1225	-27.47	251.99	5.	1226	-27.47	257.53	0.	1227	-27.47	263.07	-5.	1228	-27.47	268.61	-6.
1229	-27.47	274.15	-5.	1230	-27.47	279.68	-6.	1231	-27.47	285.22	4.	1232	-27.47	290.76	80.
1233	-27.47	296.30	7.	1234	-27.47	301.84	13.	1235	-27.47	307.38	8.	1236	-27.47	312.91	-5.
1237	-27.47	318.45	-24.	1238	-27.47	323.99	-16.	1239	-27.47	329.53	-8.	1240	-27.47	335.07	-11.
1241	-27.47	340.61	-3.	1242	-27.47	346.14	0.	1243	-27.47	351.68	-1.	1244	-27.47	357.22	-4.
1245	-32.50	2.95	25.	1246	-32.50	8.85	9.	1247	-32.50	14.75	10.	1248	-32.50	20.66	9.
1249	-32.50	26.56	17.	1250	-32.50	32.46	20.	1251	-32.50	38.36	-25.	1252	-32.50	44.26	8.
1253	-32.50	50.16	23.	1254	-32.50	56.07	20.	1255	-32.50	61.97	-7.	1256	-32.50	67.87	14.
1257	-32.50	73.77	32.	1258	-32.50	79.67	0.	1259	-32.50	85.57	-13.	1260	-32.50	91.48	-1.
1261	-32.50	97.38	-29.	1262	-32.50	103.28	-34.	1263	-32.50	109.18	-35.	1264	-32.50	115.08	4.
1265	-32.50	120.98	-8.	1266	-32.50	126.89	-12.	1267	-32.50	132.79	-8.	1268	-32.50	138.69	3.
1269	-32.50	144.59	2.	1270	-32.50	150.49	28.	1271	-32.50	156.40	7.	1272	-32.50	162.30	-13.
1273	-32.50	168.20	-23.	1274	-32.50	174.10	-13.	1275	-32.50	180.00	1.	1276	-32.50	185.90	-38.
1277	-32.50	191.81	-8.	1278	-32.50	197.71	-10.	1279	-32.50	203.61	-4.	1280	-32.50	209.51	10.
1281	-32.50	215.41	-9.	1282	-32.50	221.31	-4.	1283	-32.50	227.22	-7.	1284	-32.50	233.12	-1.
1285	-32.50	239.02	3.	1286	-32.50	244.92	2.	1287	-32.50	250.82	-14.	1288	-32.50	256.72	-2.
1289	-32.50	262.63	-8.	1290	-32.50	268.53	-6.	1291	-32.50	274.43	-6.	1292	-32.50	280.33	-5.
1293	-32.50	286.23	14.	1294	-32.50	292.13	26.	1295	-32.50	298.04	13.	1296	-32.50	303.94	24.
1297	-32.50	309.84	9.	1298	-32.50	315.74	-14.	1299	-32.50	321.64	-13.	1300	-32.50	327.54	21.
1301	-32.50	333.45	4.	1302	-32.50	339.35	7.	1303	-32.50	345.25	6.	1304	-32.50	351.15	4.
1305	-32.50	357.05	12.	1306	-37.47	3.16	4.	1307	-37.47	9.47	0.	1308	-37.47	15.79	-2.
1309	-37.47	22.11	-2.	1310	-37.47	28.42	6.	1311	-37.47	34.74	11.	1312	-37.47	41.05	16.
1313	-37.47	47.37	2.	1314	-37.47	53.69	-2.	1315	-37.47	60.00	3.	1316	-37.47	66.32	0.
1317	-37.47	72.63	-1.	1318	-37.47	78.95	-4.	1319	-37.47	85.26	-10.	1320	-37.47	91.58	-2.
1321	-37.47	97.90	-19.	1322	-37.47	104.21	-34.	1323	-37.47	110.53	-47.	1324	-37.47	116.84	-40.
1325	-37.47	123.16	-59.	1326	-37.47	129.48	-11.	1327	-37.47	135.79	-25.	1328	-37.47	142.11	7.
1329	-37.47	148.42	19.	1330	-37.47	154.74	5.	1331	-37.47	161.06	-3.	1332	-37.47	167.37	42.
1333	-37.47	173.69	32.	1334	-37.47	180.00	-11.	1335	-37.47	186.32	-15.	1336	-37.47	192.63	-18.
1337	-37.47	198.95	-28.	1338	-37.47	205.27	-9.	1339	-37.47	211.58	-7.	1340	-37.47	217.90	-9.
1341	-37.47	224.21	-10.	1342	-37.47	230.53	-6.	1343	-37.47	236.85	-6.	1344	-37.47	243.16	9.
1345	-37.47	249.48	-3.	1346	-37.47	255.79	-3.	1347	-37.47	262.11	-9.	1348	-37.47	268.43	-2.

No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG	No	φ	λ	ΔG
1349	-37.47	279.74	-24.	1350	-37.47	281.06	-12.	1351	-37.47	287.37	32.	1352	-37.47	293.69	3.
1353	-37.47	300.01	11.	1354	-37.47	306.32	1.	1355	-37.47	312.64	-34.	1356	-37.47	318.95	-41.
1357	-37.47	325.27	6.	1358	-37.47	331.58	4.	1359	-37.47	337.90	3.	1360	-37.47	344.22	0.
1361	-37.47	350.53	12.	1362	-37.47	356.85	16.	1363	-42.47	3.33	-2.	1364	-42.47	10.00	-2.
1365	-42.47	16.67	-8.	1366	-42.47	23.33	11.	1367	-42.47	30.00	11.	1368	-42.47	36.67	9.
1369	-42.47	43.33	13.	1370	-42.47	50.00	21.	1371	-42.47	56.67	15.	1372	-42.47	63.33	10.
1373	-42.47	70.00	6.	1374	-42.47	76.67	-7.	1375	-42.47	83.33	-1.	1376	-42.47	90.00	1.
1377	-42.47	96.67	3.	1378	-42.47	103.33	4.	1379	-42.47	110.00	8.	1380	-42.47	116.67	-8.
1381	-42.47	123.33	-20.	1382	-42.47	130.00	-10.	1383	-42.47	136.67	-25.	1384	-42.47	143.33	19.
1385	-42.47	150.00	12.	1386	-42.47	156.67	1.	1387	-42.47	163.33	-8.	1388	-42.47	170.00	23.
1389	-42.47	176.67	5.	1390	-42.47	183.33	-14.	1391	-42.47	190.00	3.	1392	-42.47	196.67	13.
1393	-42.47	203.33	9.	1394	-42.47	210.00	1.	1395	-42.47	216.67	4.	1396	-42.47	223.33	4.
1397	-42.47	230.00	3.	1398	-42.47	236.67	2.	1399	-42.47	243.33	2.	1400	-42.47	250.00	-4.
1401	-42.47	256.67	3.	1402	-42.47	263.33	-1.	1403	-42.47	270.00	-5.	1404	-42.47	276.67	-24.
1405	-42.47	283.33	28.	1406	-42.47	290.00	47.	1407	-42.47	296.67	3.	1408	-42.47	303.33	-5.
1409	-42.47	310.00	-18.	1410	-42.47	316.67	-16.	1411	-42.47	323.33	-7.	1412	-42.47	330.00	-1.
1413	-42.47	336.67	-2.	1414	-42.47	343.33	7.	1415	-42.47	350.00	33.	1416	-42.47	356.67	20.
1417	-47.48	3.67	3.	1418	-47.48	11.02	2.	1419	-47.48	18.37	2.	1420	-47.48	25.71	12.
1421	-47.48	33.06	13.	1422	-47.48	40.41	11.	1423	-47.48	47.75	14.	1424	-47.48	55.10	14.
1425	-47.48	62.45	11.	1426	-47.48	69.80	28.	1427	-47.48	77.14	9.	1428	-47.48	84.49	0.
1429	-47.48	91.84	1.	1430	-47.48	99.18	-2.	1431	-47.48	106.53	-2.	1432	-47.48	113.88	-7.
1433	-47.48	121.22	-29.	1434	-47.48	128.57	-24.	1435	-47.48	135.92	-21.	1436	-47.48	143.26	-16.
1437	-47.48	150.61	-20.	1438	-47.48	157.96	-8.	1439	-47.48	165.31	8.	1440	-47.48	172.65	53.
1441	-47.48	180.00	-1.	1442	-47.48	187.35	-7.	1443	-47.48	194.69	0.	1444	-47.48	202.04	-26.
1445	-47.48	209.39	1.	1446	-47.48	216.73	-4.	1447	-47.48	224.08	-4.	1448	-47.48	231.43	-6.
1449	-47.48	238.77	-3.	1450	-47.48	246.12	2.	1451	-47.48	253.47	-1.	1452	-47.48	260.81	2.
1453	-47.48	268.16	-10.	1454	-47.48	275.51	17.	1455	-47.48	282.86	11.	1456	-47.48	290.20	-9.
1457	-47.48	297.55	-4.	1458	-47.48	304.90	-17.	1459	-47.48	312.24	3.	1460	-47.48	319.59	-20.
1461	-47.48	326.94	-32.	1462	-47.48	334.28	4.	1463	-47.48	341.63	5.	1464	-47.48	348.98	15.
1465	-47.48	356.32	11.	1466	-52.46	4.09	-2.	1467	-52.46	12.27	-12.	1468	-52.46	20.46	-1.
1469	-52.46	28.04	0.	1470	-52.46	36.82	16.	1471	-52.46	45.00	14.	1472	-52.46	53.18	17.
1473	-52.46	61.36	24.	1474	-52.46	69.55	21.	1475	-52.46	77.73	3.	1476	-52.46	85.91	-6.
1477	-52.46	94.09	1.	1478	-52.46	102.27	6.	1479	-52.46	110.46	8.	1480	-52.46	118.64	-11.
1481	-52.46	126.82	-17.	1482	-52.46	135.00	-13.	1483	-52.46	143.18	-16.	1484	-52.46	151.37	-16.
1485	-52.46	159.55	-24.	1486	-52.46	167.73	-1.	1487	-52.46	175.91	4.	1488	-52.46	184.09	-4.
1489	-52.46	192.27	7.	1490	-52.46	200.46	-27.	1491	-52.46	208.64	12.	1492	-52.46	216.82	-3.
1493	-52.46	225.00	16.	1494	-52.46	233.18	-3.	1495	-52.46	241.37	6.	1496	-52.46	249.55	-4.
1497	-52.46	257.73	-1.	1498	-52.46	265.91	2.	1499	-52.46	274.09	-1.	1500	-52.46	282.28	6.
1501	-52.46	290.46	-7.	1502	-52.46	298.64	12.	1503	-52.46	306.82	-7.	1504	-52.46	315.00	18.
1505	-52.46	323.19	-4.	1506	-52.46	331.37	-10.	1507	-52.46	339.55	0.	1508	-52.46	347.73	13.
1509	-52.46	355.91	16.	1510	-57.42	4.62	1.	1511	-57.42	13.85	1.	1512	-57.42	23.08	16.
1513	-57.42	32.31	1.	1514	-57.42	41.54	-3.	1515	-57.42	50.77	1.	1516	-57.42	60.00	-9.
1517	-57.42	69.23	-10.	1518	-57.42	78.46	3.	1519	-57.42	87.69	5.	1520	-57.42	96.92	-4.
1521	-57.42	106.15	-8.	1522	-57.42	115.39	-3.	1523	-57.42	124.62	-4.	1524	-57.42	133.85	12.
1525	-57.42	143.08	3.	1526	-57.42	152.31	0.	1527	-57.42	161.54	3.	1528	-57.42	170.77	0.
1529	-57.42	180.00	-2.	1530	-57.42	189.23	2.	1531	-57.42	198.46	-7.	1532	-57.42	207.69	0.
1533	-57.42	216.92	-31.	1534	-57.42	226.15	-3.	1535	-57.42	235.39	-29.	1536	-57.42	244.62	-1.
1537	-57.42	253.85	5.	1538	-57.42	263.08	14.	1539	-57.42	272.31	-20.	1540	-57.42	281.54	-11.
1541	-57.42	290.77	19.	1542	-57.42	300.00	31.	1543	-57.42	309.23	19.	1544	-57.42	318.46	7.
1545	-57.42	327.69	-8.	1546	-57.42	336.92	-8.	1547	-57.42	346.15	0.	1548	-57.42	355.39	1.
1549	-62.42	5.27	2.	1550	-62.42	15.88	-10.	1551	-62.42	26.47	-1.	1552	-62.42	37.06	-1.
1553	-62.42	47.65	4.	1554	-62.42	58.24	-1.	1555	-62.42	68.82	11.	1556	-62.42	79.41	-3.
1557	-62.42	90.00	-12.	1558	-62.42	100.59	11.	1559	-62.42	111.18	23.	1560	-62.42	121.77	11.
1561	-62.42	132.35	8.	1562	-62.42	142.94	1.	1563	-62.42	153.53	-3.	1564	-62.42	164.12	-6.
1565	-62.42	174.71	0.	1566	-62.42	185.30	4.	1567	-62.42	195.88	-2.	1568	-62.42	206.47	10.
1569	-62.42	217.06	2.	1570	-62.42	227.65	15.	1571	-62.42	238.24	-2.	1572	-62.42	248.83	12.
1573	-62.42	259.41	5.	1574	-62.42	270.00	5.	1575	-62.42	280.59	8.	1576	-62.42	291.18	8.

HARMOGRAV

Appendix B

Geometric and Physical Constants

Related to HARMOGRAV

GEOMETRIC CONSTANTS:		REFERENCES	
E	= linear eccentricity $= \sqrt{a^2 - b^2}$	2.,p.32	= 521862.81m
e^2	= first eccentricity $= \frac{a^2 - b^2}{a^2} = 3J_2 + \frac{4}{15} \frac{\omega^2 a^3}{GM} \frac{e^3}{2qo}$	2.,p.30	= 0.006694557445
e'^2	= second eccentricity $= \frac{e^2}{1 - e^2}$	2.,p.30	= 0.006739676597
f	= flattening, equation by Kovalevsky	2.,p.48	= 0.003352899691(1/298.2493)
b	= semiminor axis $= a - af = a\sqrt{1-e^2}$	2.,p.32	= 6356774.67m
PHYSICAL CONSTANTS:			
U_o	= normal potential at ellipsoid $= \frac{GM}{E} \arctan e' + 1/3\omega^2 a^2$	2.,p.34	= 62637030.06$m^2 sec^{-2}$
J_2	= constant in the spherical harmonic expansion of the gravity field = "GRS 67" $J_2 + (-\delta C_{20})$		= 0.001082684
J_4	= spherical harmonic coefficient $= -4/5f^2 + 4/7fm$	4.,p.78	= -2.383927×10^{-6}
m	= constant $= \omega^2 a^2 b/GM$	2.,p.30	= 0.0034[illegible]98015177
γ_e	= normal gravity at equator, equation by J. Kovalevsky	2.,p.48	= 978031.823 mgal
γ_p	= normal gravity at pole $= GM/a^2 \left(1 + \frac{m}{3} \frac{e'qo'}{qo}\right)$	2.,p.36	= 983217.729 mgal
β	= gravity flattening $= \frac{\gamma_p - \gamma_e}{\gamma_e}$	2.,p.36	= 0.00530239
β_1	= gravity coefficient $= (-5/8fc + 0.125f^2)$	3.,p.52	= 0.00000585

β_2	=	gravity coefficient	$= 3/8f^2\beta + 1/4f^3$	5.,p.64	$= 0.317766946 \times 10^{-7}$
β_3	=	gravity coefficient	$= 1/2f^3\beta + 3/8f^4$	5.,p.64	$= 0.1473246 \times 10^{-9}$
q_o	=	gravity coefficients	$= ((1 + 3/e'^2)\arctan e' - \frac{3}{e'})/2$	2.,p.30	$= 0.000073349182$
q_o'	=	gravity coefficients	$= 3(1+1/e'^2)(1 - 1/e' \arctan e')-1$	2.,p.36	$= 0.002688112822$
A_{oo}	=	spherical harmonic	$= \gamma_e(1 + 1/3\beta - 8/15\beta_1 - 8/35\beta_2 - 23/35\beta_3)$	2.,p.63	= 979757.3998 mgals
A_{20}	=	spherical harmonic	$= \gamma_e(2/3\beta - 8/21\beta_1 - 8/21\beta_2 - 64/231\beta_3)$	5.,p.63	= 3455.08 mgals
A_{40}	=	spherical harmonic	$= {}_e(32/35\beta_1 + 125/385\beta_2 + 184/5005\beta_3)$	5.,p.63	= 5.24 mgals

ADOPTED CONSTANTS

GM	=	gravitational constant	2.,p.8	$= 3.98603 \times 10^{14} m^3 sec^{-2}$
a	=	semimajor axis	2.,p.8	= 6378160.0m
ω	=	angular velocity	2.,p.26	$= 7.2921151467 \times 10^{-5}$ rad./sec

NORMAL GRAVITY FORMULA

$$\gamma = 978.031823\ (1 + 0.00530239 \sin^2\phi - 0.00000585 \sin^2 2\phi)\text{gal}$$

NORMAL GRAVITY FORMULA EXPRESSED IN TERMS OF SPHERICAL HARMONICS

$$\gamma = 979757.4 + 3455.08\ P_{20} + 5.24\ P_{40}$$

The above listed parameters differ very slightly from the parameters of GRS 67, listed in [1].

HARMOGRAV

Appendix C

HARMOGRAV Geopotential Coefficients

36 Degree 36 Order

TABLE C-1

HARMOGRAV

EARTH GRAVITATIONAL MODEL

Degree and Order		Normalized Geopotential Coefficients		Degree and Order		Normalized Geopotential Coefficients	
n	m	$\bar{C}_{nm}$	$\bar{S}_{nm}$	n	m	$\bar{C}_{nm}$	$\bar{S}_{nm}$
2	0 *	7.1920-009		8	0	3.4016-008	
2	1	3.8714-010	-1.6143-008	8	1	-1.3414-007	1.3866-007
2	2	4.1636-006	-1.4744-006	8	2	2.3061-008	1.1521-007
3	0	2.8415-007		8	3	2.4980-008	1.0133-008
3	1	1.5287-006	-3.7002-007	8	4	-5.3437-008	1.5605-008
3	2	9.2610-007	-3.9012-007	8	5	-9.2533-008	1.4492-007
3	3	9.0414-007	1.7579-006	8	6	4.9123-009	1.2694-007
4	0 *	1.6526-009		8	7	-1.7269-008	1.2205-007
4	1	-1.5023-007	-2.6514-007	8	8	-2.4501-007	1.2567-007
4	2	3.6068-007	4.4729-007	9	0	1.1429-007	
4	3	9.9917-007	-1.9502-007	9	1	5.1022-008	-1.0490-008
4	4	-1.4010-007	2.8979-007	9	2	4.3309-008	-6.4226-009
5	0	2.0596-008		9	3	-1.9064-007	-6.6314-008
5	1	-3.4556-007	-2.3069-007	9	4	-2.0907-008	-8.2533-008
5	2	6.3123-007	-2.1000-007	9	5	-1.3660-007	1.8452-008
5	3	-3.9246-007	-2.8620-008	9	6	5.2235-008	1.4852-007
5	4	-1.4847-007	1.5858-007	9	7	-5.1761-008	4.3997-008
5	5	2.0088-007	-5.3066-007	9	8	2.4294-007	5.0860-008
6	0	-7.1803-008		9	9	2.1597-008	6.1243-008
6	1	1.9946-007	-4.6910-009	10	0	2.6942-008	
6	2	3.4999-007	-1.2167-007	10	1	4.7869-008	-3.7387-008
6	3	-1.2607-007	-8.1337-008	10	2	-1.1029-007	-1.0227-007
6	4	-1.3582-007	-4.5262-007	10	3	-9.0147-008	-1.9897-007
6	5	-4.3390-007	-6.3805-007	10	4	-5.6412-008	-7.4054-008
6	6	7.9459-008	-2.1712-007	10	5	4.2268-008	-8.7467-009
7	0	1.8260-007		10	6	-6.1336-008	-1.1662-007
7	1	2.6126-007	1.1136-007	10	7	1.2574-007	-3.3921-009
7	2	3.0426-007	2.5159-007	10	8	-7.5927-009	-1.2414-007
7	3	1.3427-007	-2.3552-007	10	9	7.4967-008	-7.9619-008
7	4	-2.7472-007	-1.6816-007	10	10	8.5392-008	-1.3874-008
7	5	4.9288-008	8.5824-008	11	0	-5.5152-008	
7	6	-3.7947-007	1.5606-007	11	1	-7.5166-009	9.0523-009
7	7	6.3297-008	-6.5358-008	11	2	-7.2434-008	-1.5291-007

* Represents δ Values

TABLE C-1 (Cont'd)

HARMOGRAV

EARTH GRAVITATIONAL MODEL

Degree and Order		Normalized Geopotential Coefficients		Degree and Order		Normalized Geopotential Coefficients	
n	m	$\bar{C}_{nm}$	$\bar{S}_{nm}$	n	m	$\bar{C}_{nm}$	$\bar{S}_{nm}$
11	3	9.5592-008	-1.3298-007	14	0	-2.1068-009	
11	4	-7.8768-008	-1.3506-007	14	1	-4.2580-008	5.0677-009
11	5	1.0825-008	-1.9851-009	14	2	-6.8550-008	4.1682-009
11		-7.7134-008	-1.8640-008	14	3	2.1343-008	1.8188-008
11	7	1.0356-007	-9.3104-008	14	4	4.6323-008	-9.9765-009
11	8	3.0171-009	6.8575-008	14	5	3.7946-008	-3.8937-008
11	9	-3.3828-008	4.8479-008	14	6	8.2526-009	5.0343-008
11	10	-1.4914.008	-4.4214-008	14	7	2.4649-008	-3.1304-008
11	11	1.4070-007	8.1357-009	14	8	-1.9824-008	-2.4645-008
12	0	-4.4590-008		14	9	1.5850-008	7.3420-008
12	1	-1.0897-007	-5.7388-008	14	10	9.9278-008	-3.4855-008
12	2	2.1290-008	1.2000-008	14	11	1.8193-008	-3.9388-008
12	3	6.8139-008	2.6953-008	14	12	2.5729-008	-7.7754-008
12	4	-7.5692-008	7.2521-009	14	13	7.7814-009	4.7394-008
12	5	9.1987-008	-3.8863-010	14	14	-5.9701-008	3.5530-008
12	6	3.4284-008	-5.6109-009	15	0	-4.5103-008	
12	7	-8.6973-008	4.6603-008	15	1	2.4732-008	3.0998-008
12	8	-8.2156-009	4.9523-008	15	2	-1.1782-008	-4.9191-008
12	9	1.0670-008	-2.6522-008	15	3	3.3258-008	5.0235-008
12	10	3.0414-008	-3.7557-008	15	4	-2.1177-008	9.9942-009
12	11	-2.7730-008	-1.6193-008	15	5	-7.8042-009	1.5587-008
12	12	3.0637-008	9.7006-009	15	6	2.5526-008	-8.7010-008
13	0	-4.5883-010		15	7	3.1437-008	3.3045-008
13	1	8.5961-009	1.2455-008	15	8	-4.7953-008	4.3200-008
13	2	3.0577-008	-5.5277-008	15	9	-5.9582-008	3.1683-008
13	3	9.2792-009	3.4575-008	15	10	7.0998-010	-3.6743-008
13	4	1.9891-008	1.6174-008	15	11	9.2789-009	-1.0833-008
13	5	6.4885-008	2.3887-008	15	12	-2.0387-008	1.1796-008
13	6	-8.5563-008	2.5221-008	15	13	-3.1750-008	1.9672-008
13	7	-2.5202-008	1.1764-008	15	14	2.1013-009	-2.0339-008
13	8	-3.3410-008	-2.7398-008	15	15	-2.7551-008	3.7285-008
13	9	1.9269-008	8.8352-009	16	0	1.5517-008	
13	10	1.1538-008	1.1958-008	16	1	-3.7467-009	2.9770-009
13	11	-3.1525-008	3.9713-008	16	2	-5.0537-008	2.3940-008
13	12	4.9529-009	9.4494-008	16	3	7.7898-009	3.7891-008
13	13	-1.2771-008	7.3414-008	16	4	4.0122-008	5.2490-008

TABLE C-1 (Cont'd)

HARMOGRAV

EARTH GRAVITATIONAL MODEL

Degree and Order n	m	Normalized Geopotential Coefficients $\bar{C}_{nm}$	$\bar{S}_{nm}$	Degree and Order n	m	Normalized Geopotential Coefficients $\bar{C}_{nm}$	$\bar{S}_{nm}$
16	5	-2.2212-009	3.6898-008	18	5	-1.1868-008	2.3511-008
16	6	-2.1438-009	1.5548-009	18	6	-1.5466-008	-6.8291-008
16	7	-1.7891-008	-3.7178-010	18	7	-1.9762-008	1.3016-008
16	8	-1.8468-008	-2.1812-008	18	8	4.2446-008	-3.3737-008
16	9	-7.6852-009	-1.5968-008	18	9	1.1654-008	4.2173-008
16	10	-9.3597-009	-4.3785-008	18	10	2.6615-008	-3.6699-008
16	11	-1.4145-008	2.0365-008	18	11	1.4887-008	2.1456-008
16	12	1.6132-008	-2.1089-008	18	12	-1.4743-008	-1.4890-008
16	13	4.1841-008	-1.4123-008	18	13	-1.5862-008	-2.0117-008
16	14	-1.4074-008	-4.8666-008	18	14	1.6259-008	-3.0639-008
16	15	-2.4810-008	-4.4174-008	18	15	-6.2292-008	-2.4294-008
16	16	-8.8636-009	3.2076-009	18	16	2.2427-008	-1.0817-008
17	0	-1.1146-008		18	17	1.7065-009	-2.1401-008
17	1	-3.6177-008	-2.2977-008	18	18	3.0055-009	-1.0035-008
17	2	-7.0630-008	8.8487-008	19	0	1.3429-009	
17	3	-3.0925-008	-1.7463-008	19	1	-2.0096-008	1.7013-008
17	4	-3.8571-008	4.1554-008	19	2	2.9497-008	1.5705-008
17	5	-1.9796-008	1.8879-008	19	3	-2.8344-008	8.5305-009
17	6	-1.9995-008	-3.3210-008	19	4	-4.3207-009	-1.4070-008
17	7	1.5727-008	-3.0862-008	19	5	-4.1578-008	2.8434-008
17	8	3.3068-008	7.0116-009	19	6	-1.0485-008	9.3369-009
17	9	2.1772-009	-2.5621-008	19	7	-1.8059-009	-3.2187-008
17	10	-1.4676-008	2.9771-008	19	8	3.7160-009	-1.0161-008
17	11	2.6064-008	6.3507-009	19	9	9.9400-009	-7.6231-009
17	12	-1.3485-009	5.1759-009	19	10	-2.2156-009	-5.1994-009
17	13	2.4318-008	2.8780-008	19	11	6.6759-009	2.3676-008
17	14	-6.3836-009	4.4531-008	19	12	1.1355-008	1.8224-008
17	15	2.1080-008	3.7928-008	19	13	1.5365-009	-2.6816-008
17	16	-2.1023-008	-1.3963-008	19	14	-4.9908-009	-1.7178-008
17	17	-3.5797-008	-1.8771-008	19	15	-6.1032-009	-1.5788-008
18	0	2.9864-008		19	16	-9.5493-009	1.8083-008
18	1	-8.8654-009	-5.9994-008	19	17	9.4525-009	-2.8147-008
18	2	-9.0484-009	-2.6031-008	19	18	6.0033-008	-1.2114-008
18	3	-2.9580-008	-2.3713-008	19	19	-5.4124-009	2.9867-008
18	4	2.8303-008	-1.3323-008	20	0	-1.0316-008	

TABLE C-1 (Cont'd)

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EARTH GRAVITATIONAL MODEL

Degree and Order n	m	Normalized Geopotential Coefficients $\bar{C}_{nm}$	$\bar{S}_{nm}$
20	1	-1.7418-008	-2.0955-008
20	2	9.4963-009	-8.0889-009
20	3	-5.7805-009	-1.6359-008
20	4	-1.5665-008	-2.0888-008
20	5	-1.2548-008	1.7643-008
20	6	-1.0068-008	6.4008-009
20	7	-2.9473-008	-1.2293-008
20	8	6.1451-009	2.3091-008
20	9	3.1911-008	6.6984-009
20	10	-2.8362-008	9.6299-009
20	11	3.3081-008	-1.0844-008
20	12	-2.8854-008	-4.7186-009
20	13	6.0616-009	1.1598-008
20	14	6.8355-009	-3.3044-009
20	15	-2.9058-008	6.1067-009
20	16	-2.1390-008	-1.6274-008
20	17	2.7052-008	-3.0852-008
20	18	-7.6519-009	1.2186-009
20	19	2.2730-008	1.6787-008
20	20	3.8663-008	-1.2543-008
21	0	2.9242-008	
21	1	5.2445-009	2.2325-008
21	2	1.1801-008	1.1687-008
21	3	-1.1478-008	3.3065-008
21	4	-1.0583-008	-1.1850-008
21	5	1.8662-008	-3.0827-008
21	6	-5.2659-009	-2.2001-008
21	7	8.7323-009	2.4199-008
21	8	-1.3928-009	1.6743-008
21	9	-5.2922-009	4.8252-008
21	10	2.8442-009	-9.8021-009
21	11	7.8057-009	-1.4645-008
21	12	1.0835-008	8.5969-009
21	13	-1.4503-008	4.4932-008
21	14	2.1044-008	-1.3555-009
21	15	5.8021-009	7.9981-009
21	16	-8.3771-009	-2.6134-009
21	17	-3.5038-008	2.2762-008
21	18	3.2934-008	1.8206-009
21	19	-2.7453-008	1.7474-008
21	20	-2.7283-008	9.1455-009
21	21	-8.7230-011	-6.2872-009
22	0	-1.5974-009	
22	1	1.1848-008	1.2336-008
22	2	-2.4683-008	-3.5287-008
22	3	-3.2967-009	2.8121-008
22	4	-5.5473-009	-1.3751-008
22	5	7.4990-009	-6.1978-009
22	6	8.3672-009	-1.4775-008
22	7	2.5807-008	-8.6492-009
22	8	-4.4149-008	-1.7498-008
22	9	-6.0025-009	1.6457-008
22	10	1.9279-008	1.4854-008
22	11	5.2243-009	1.6772-009
22	12	-9.7359-009	1.6071-009
22	13	-2.1144-008	1.1081-008
22	14	5.0141-009	4.9940-009
22	15	1.5570-008	-1.6196-009
22	16	-2.4987-008	-9.7202-009
22	17	6.0414-009	-2.5014-008
22	18	-1.6601-008	-2.7089-008
22	19	1.2538-008	-5.6105-009
22	20	-2.9346-008	1.1652-008
22	21	-2.1960-008	1.8172-008
22	22	1.0311-008	-1.3009-008
23	0	-2.6431-008	
23	1	1.2477-008	1.0743-008
23	2	-1.5902-008	-2.0174-008
23	3	1.2396-008	-4.5869-010
23	4	-1.4778-008	2.6743-009
23	5	1.7239-008	1.2174-008
23	6	4.9269-009	2.8973-008

TABLE C-1 (Cont'd)

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EARTH GRAVITATIONAL MODEL

Degree and Order		Normalized Geopotential Coefficients		Degree and Order		Normalized Geopotential Coefficients	
n	m	$\bar{C}_{nm}$	$\bar{S}_{nm}$	n	m	$\bar{C}_{nm}$	$\bar{S}_{nm}$
23	7	-1.2111-008	-3.7799-009	24	20	1.1200-008	3.4819-009
23	8	-1.8470-008	-9.1053-010	24	21	8.8613-009	2.2553-008
23	9	-8.5522-009	-1.9795-008	24	22	-9.4845-009	-6.6897-009
23	10	1.0512-008	1.9866-008	24	23	6.7092-009	-1.7004-008
23	11	8.6822-009	8.7605-009	24	24	1.0639-008	1.1727-008
23	12	-3.9704-009	-2.7002-008	25	0	3.2418-009	
23	13	1.1326-009	1.9625-008	25	1	-3.9652-009	-1.2629-008
23	14	7.4903-009	4.4099-009	25	2	1.7510-008	1.6545-008
23	15	3.6550-008	-4.9531-009	25	3	-3.3126-009	-8.6364-009
23	16	1.9223-008	1.7404-008	25	4	8.9902-009	-7.2478-009
23	17	2.0812-009	-1.6898-008	25	5	1.0812-008	-1.4120-008
23	18	2.0495-008	-2.0298-008	25	6	1.8316-008	5.8409-009
23	19	1.1146-008	9.9380-009	25	7	5.5041-009	-2.6680-009
23	20	-2.1546-009	7.7723-009	25	8	8.3533-009	-1.1465-008
23	21	-5.2480-009	1.8524-008	25	9	-2.5607-008	-1.1078-008
23	22	-2.7238-008	3.9817-009	25	10	1.6260-008	7.3617-009
23	23	-7.3747-009	3.2453-009	25	11	1.5777-008	1.5648-008
24	0	-3.6683-009		25	12	-6.2836-009	7.1854-011
24	1	1.8342-008	-2.7231-008	25	13	9.7422-010	-1.6997-008
24	2	-2.8784-009	1.1513-008	25	14	-2.9391-008	-1.7484-008
24	3	-2.7279-009	-1.8000-008	25	15	1.2221-008	6.7515-009
24	4	-2.2584-008	4.2575-008	25	16	3.8250-009	6.4274-009
24	5	-1.2203-008	-1.3556-008	25	17	-9.7660-009	-2.0804-008
24	6	-1.7521-008	2.0031-008	25	18	1.4608-008	-1.7702-008
24	7	-4.3481-009	-1.8424-008	25	19	1.0868-008	-1.0202-009
24	8	1.6015-008	1.5331-008	25	20	-2.3209-008	-8.6558-009
24	9	-2.7803-008	-1.6291-008	25	21	3.4902-009	-5.9353-009
24	10	9.9306-009	1.4979-008	25	22	-1.6868-008	1.6021-008
24	11	1.2295-009	2.3273-008	25	23	9.6688-009	-2.0361-008
24	12	1.2214-008	-1.0603-008	25	24	-7.6696-009	-1.5883-008
24	13	-3.1888-009	7.8907-009	25	25	2.7679-009	1.1124-008
24	14	-3.6729-008	-2.0895-008	26	0	1.8229-008	
24	15	1.0632-008	-4.0309-009	26	1	-3.5776-010	-3.7371-010
24	16	8.2189-009	-1.8299-008	26	2	8.3373-009	3.3122-009
24	17	-2.4956-008	-2.5183-008	26	3	-7.6570-009	4.1728-009
24	18	-5.1519-009	-1.8672-008	26	4	1.1299-008	1.0448-008
24	19	-2.0205-008	-1.4866-008	26	5	4.1258-010	3.5532-009

TABLE C-1 (Cont'd)

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EARTH GRAVITATIONAL MODEL

Degree and Order		Normalized Geopotential Coefficients		Degree and Order		Normalized Geopotential Coefficients	
n	m	$\bar{C}_{nm}$	$\bar{S}_{nm}$	n	m	$\bar{C}_{nm}$	$\bar{S}_{nm}$
26	6	3.3561-008	1.1238-008	27	15	-5.2865-009	-1.8094-009
26	7	1.6282-008	1.0331-008	27	16	-4.0056-009	-1.1438-008
26	8	1.4793-008	-1.6226-008	27	17	2.1228-008	1.7322-008
26	9	-1.2468-009	1.5286-008	27	18	5.0024-009	1.3391-008
26	10	4.2411-009	-1.4889-009	27	19	1.2851-008	-3.3623-009
26	11	-1.2727-008	-6.1929-009	27	20	9.1964-009	-2.4259-009
26	12	-1.5311-008	-1.3256-008	27	21	1.7147-008	4.2131-009
26	13	1.3532-008	9.8504-009	27	22	-7.1337-009	6.0866-009
26	14	2.1334-008	1.1606-008	27	23	-1.6322-008	-1.1016-008
26	15	-7.3397-009	2.0053-010	27	24	-3.1128-008	-4.1018-009
26	16	3.8187-009	7.4777-010	27	25	-9.4192-009	1.3764-008
26	17	-1.0323-008	1.5200-009	27	26	-4.5843-009	-2.3274-008
26	18	-2.0224-008	2.4274-008	27	27	1.0615-009	3.4082-009
26	19	-1.0825-008	1.5530-008	28	0	-1.4255-008	
26	20	-2.5342-010	-8.0817-009	28	1	7.1638-009	2.2896-008
26	21	-7.7322-009	-6.3184-010	28	2	3.6095-009	-1.3565-008
26	22	9.4859-009	-2.3009-008	28	3	-1.0572-008	9.6040-009
26	23	2.8110-008	3.7900-009	28	4	-2.1288-008	-1.7622-010
26	24	2.0313-008	3.7516-008	28	5	-4.9099-009	-6.7219-009
26	25	-1.0068-009	-8.1348-010	28	6	5.4139-009	1.0636-008
26	26	7.0669-009	8.1660-009	28	7	1.1936-008	2.6203-008
27	0	2.0738-008		28	8	4.0631-009	5.8303-009
27	1	8.8217-009	-2.3668-009	28	9	1.0979-009	-3.5548-009
27	2	9.4254-009	4.1037-009	28	10	-5.4397-009	7.7581-009
27	3	-2.3738-009	7.7361-010	28	11	2.3107-008	8.6482-009
27	4	2.0609-009	3.3575-008	28	12	7.5703-010	1.0443-008
27	5	2.7578-008	-7.3096-009	28	13	5.6288-010	-3.8194-009
27	6	1.7461-008	-5.2335-009	28	14	-2.4343-008	-3.6990-009
27	7	-8.0667-009	-1.9623-009	28	15	2.5368-010	1.0348-008
27	8	-1.3985-008	-3.7263-009	28	16	4.2013-009	-6.7259-009
27	9	2.0466-008	5.1046-009	28	17	-3.4380-009	-7.6631-010
27	10	3.9199-009	1.3041-008	28	18	-6.1370-009	-1.1776-008
27	11	-1.9469-009	-1.9137-008	28	19	-1.3330-008	4.3750-009
27	12	9.9709-009	1.0107-008	28	20	-3.5478-009	-4.3041-009
27	13	1.0785-008	8.6297-009	28	21	6.1312-009	3.2599-009
27	14	-7.2241-009	8.1321-009	28	22	8.4227-010	1.5782-009

TABLE C-1 (Cont'd)

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EARTH GRAVITATIONAL MODEL

Degree and Order n	m	Normalized Geopotential Coefficients $\bar{C}_{nm}$	$\bar{S}_{nm}$	Degree and Order n	m	Normalized Geopotential Coefficients $\bar{C}_{nm}$	$\bar{S}_{nm}$
28	23	2.0838-008	-6.2203-009	30	0	-2.1770-008	
28	24	2.7347-008	-7.8555-009	30	1	-3.3508-009	1.6023-008
28	25	-3.6277-009	-3.6037-008	30	2	-6.6860-009	-8.2487-009
28	26	9.6425-009	4.8878-009	30	3	-1.6291-008	-1.6935-008
28	27	1.0161-008	-6.3833-009	30	4	9.5883-009	1.6783-008
28	28	-5.6798-009	1.3429-008	30	5	-6.7281-010	-1.2530-008
29	0	-8.8958-009		30	6	9.3244-009	2.1910-008
29	1	1.6664-010	1.4109-009	30	7	1.5509-008	-5.7838-009
29	2	-4.4202-009	4.7576-009	30	8	-6.5129-009	9.2913-009
29	3	1.6342-008	1.2629-009	30	9	-2.2258-009	-3.6670-009
29	4	-1.6994-008	-1.0952-008	30	10	-2.8472-011	-1.0943-008
29	5	-2.6703-009	9.2807-009	30	11	-2.6419-009	-7.9973-009
29	6	-2.4386-009	8.7348-009	30	12	1.3099-008	1.5570-009
29	7	-5.9514-009	-1.5037-008	30	13	1.2507-008	8.6023-010
29	8	6.7723-010	5.4121-009	30	14	9.6729-009	-1.0610-008
29	9	-7.8356-009	5.9941-009	30	15	3.0713-009	1.3366-008
29	10	8.8283-009	2.9007-008	30	16	-1.2069-008	-1.9636-009
29	11	-6.9127-009	1.4687-008	30	17	-5.5086-009	-1.7811-008
29	12	6.9948-009	9.8251-009	30	18	-8.3779-009	-1.6221-008
29	13	-1.7023-009	-2.9199-009	30	19	-6.6986-009	1.8758-009
29	14	8.5182-009	-1.3990-008	30	20	-1.1326-008	7.0701-010
29	15	-1.0760-008	1.0421-008	30	21	6.3691-009	-9.5149-010
29	16	-1.1535-008	-2.9255-008	30	22	-6.0798-009	-8.5191-009
29	17	-5.6526-009	-8.5299-009	30	23	1.0700-009	5.3010-009
29	18	-6.0275-009	5.4782-009	30	24	-3.8573-010	8.8377-009
29	19	-1.9800-008	7.8633-009	30	25	-8.7675-009	-3.3416-009
29	20	-4.6644-009	-8.8905-010	30	26	1.2245-008	-7.9151-009
29	21	-8.1826-009	-7.2600-009	30	27	2.5625-009	1.4940-008
29	22	1.4311-008	-2.5853-010	30	28	-1.1688-008	-8.7843-009
29	23	9.0159-009	1.6619-008	30	29	-1.6599-008	1.0277-009
29	24	-2.3351-009	4.2995-009	30	30	6.4634-009	9.6689-010
29	25	-2.9882-009	1.7205-008	31	0	-1.6932-009	
29	26	-1.1839-008	4.7132-010	31	1	6.9002-009	-3.2871-008
29	27	-2.5322-008	-5.2973-009	31	2	8.9883-010	-1.8217-009
29	28	-4.6802-009	-7.6977-010	31	3	-2.1185-009	-1.1658-008
29	29	2.1593-008	-1.3481-008	31	4	-1.2365-010	-1.1493-008

TABLE C-1 (Cont'd)

HARMOGRAV

EARTH GRAVITATIONAL MODEL

Degree and Order		Normalized Geopotential Coefficients		Degree and Order		Normalized Geopotential Coefficients	
n	m	$\bar{C}_{nm}$	$\bar{S}_{nm}$	n	m	$\bar{C}_{nm}$	$\bar{S}_{nm}$
31	5	1.0080-008	-6.0146-009	32	9	3.7749-009	-1.2496-008
31	6	-5.0845-009	9.8456-009	32	10	7.2747-009	-1.1647-008
31	7	1.6923-009	-3.4212-009	32	11	-1.8228-009	1.2906-008
31	8	1.0732-008	3.5095-009	32	12	4.9806-009	2.4349-008
31	9	-4.6729-009	5.9928-009	32	13	-2.5182-009	-2.6293-009
31	10	-5.2176-009	9.2648-009	32	14	4.1561-009	3.3292-009
31	11	7.4209-010	1.7658-008	32	15	1.8037-008	-1.0397-008
31	12	1.2821-008	-1.5037-008	32	16	6.3821-009	-4.9940-009
31	13	9.2012-009	1.0117-008	32	17	-5.1489-009	2.4058-008
31	14	-2.1207-008	4.9653-010	32	18	1.0111-008	-1.0133-008
31	15	7.0456-009	-9.8074-010	32	19	6.1332-010	8.1722-009
31	16	-1.2143-008	-1.5477-009	32	20	-2.3962-009	-3.6060-009
31	17	-4.2389-009	-1.7734-010	32	21	9.6297-010	6.5385-010
31	18	5.4699-009	-7.6421-009	32	22	-1.1488-008	-8.2425-009
31	19	-8.4632-010	-9.9970-009	32	23	-2.6723-009	-6.8337-009
31	20	1.2485-008	1.3051-008	32	24	-7.3106-009	3.6428-009
31	21	-3.0593-009	1.1319-008	32	25	-1.9380-008	1.2894-008
31	22	7.4952-009	5.9595-009	32	26	-5.2796-009	4.7498-009
31	23	9.3283-009	1.0546-008	32	27	1.4839-008	-1.5705-009
31	24	-4.7489-009	2.2528-008	32	28	5.2486-009	-4.7670-009
31	25	-2.0998-008	-4.0930-009	32	29	1.2495-008	-3.4335-009
31	26	-1.3183-008	-7.1439-011	32	30	8.3172-009	-1.1662-008
31	27	-7.7371-009	-4.5024-009	32	31	-5.9841-009	-3.5921-009
31	28	1.2996-008	1.3028-008	32	32	-1.2470-008	3.2328-009
31	29	-9.3617-009	5.5192-009	33	0	1.0765-008	
31	30	-2.1935-008	7.5223-009	33	1	6.7366-009	-8.9765-010
31	31	-5.2880-009	8.6702-009	33	2	1.1215-008	-1.7496-008
32	0	-8.1376-009		33	3	6.9965-010	1.9654-008
32	1	1.2346-009	-1.6821-009	33	4	-9.1302-009	1.7181-008
32	2	1.0875-008	-1.0814-008	33	5	7.5552-009	2.4072-008
32	3	5.6385-009	-7.3007-009	33	6	-3.1229-009	-2.0349-009
32	4	-9.3093-010	2.7371-009	33	7	-3.0487-008	-3.3296-009
32	5	2.2133-008	2.3414-008	33	8	5.8711-009	2.6116-008
32	6	9.4587-009	-1.7077-008	33	9	1.1496-008	5.1349-009
32	7	7.9634-009	7.0317-009	33	10	6.2998-009	-1.4666-008
32	8	1.9899-008	-6.9606-009	33	11	3.3616-009	-2.0414-009

TABLE C-1 (Cont'd)

HARMOGRAV

EARTH GRAVITATIONAL MODEL

Degree and Order		Normalized Geopotential Coefficients		Degree and Order		Normalized Geopotential Coefficients	
n	m	$\bar{C}_{nm}$	$\bar{S}_{nm}$	n	m	$\bar{C}_{nm}$	$\bar{S}_{nm}$
33	12	8.3831-009	-6.9641-009	34	13	-1.1213-009	-3.2882-011
33	13	1.4664-008	-2.4665-009	34	14	6.2121-009	-3.9087-009
33	14	2.8437-010	2.4627-009	34	15	-1.2635-008	4.1618-009
33	15	7.0293-009	2.2800-009	34	16	-4.6049-009	1.6258-009
33	16	3.1104-009	5.3999-009	34	17	-1.6466-009	1.0472-008
33	17	1.4401-008	1.5692-008	34	18	-1.2481-008	-4.1103-009
33	18	-1.6798-009	-5.6957-009	34	19	-7.8401-009	7.1572-009
33	19	1.5890-008	5.6169-009	34	20	-1.1090-008	-1.1153-008
33	20	1.4039-008	-9.1327-010	34	21	-1.1069-008	-1.1624-008
33	21	-2.7041-009	6.2430-009	34	22	8.9187-009	1.4358-009
33	22	3.2089-009	-1.8102-009	34	23	4.1902-009	-5.6155-009
33	23	-2.9084-009	7.5115-009	34	24	-1.4228-008	-1.8777-009
33	24	3.1333-009	-6.9970-009	34	25	-6.5178-009	3.6710-010
33	25	2.1047-009	3.0410-010	34	26	-6.4376-009	-3.8198-009
33	26	-8.3017-010	-1.1296-008	34	27	1.6596-008	-1.0517-008
33	27	-2.9807-009	6.1953-009	34	28	9.0023-009	-1.0068-008
33	28	-2.1563-009	1.0877-009	34	29	-2.4011-009	-1.9435-008
33	29	-1.8334-008	1.4920-008	34	30	-2.3681-009	8.1140-009
33	30	-9.5332-009	-1.5737-008	34	31	-1.0506-008	-5.1814-009
33	31	1.4452-008	4.6550-009	34	32	3.7267-009	-2.1066-009
33	32	3.5245-008	2.7248-009	34	33	1.0609-008	9.6473-010
33	33	1.9853-008	9.0512-009	34	34	-1.4526-008	-1.1003-008
34	0	-3.6943-008		35	0	2.7228-008	
34	1	4.2606-009	5.1151-009	35	1	-2.3055-009	-2.6808-010
34	2	-1.0910-008	-3.1817-009	35	2	1.5743-008	1.9118-008
34	3	2.9330-009	-4.7219-009	35	3	3.6577-009	-1.2250-010
34	4	1.2750-008	1.3457-008	35	4	-5.0144-008	1.8754-008
34	5	-1.0784-008	1.4755-008	35	5	-1.3560-008	5.9068-009
34	6	1.5739-008	3.3206-009	35	6	3.1720-009	1.7390-008
34	7	5.6570-009	-6.4862-009	35	7	-6.1502-010	6.8109-009
34	8	4.9865-009	8.3597-011	35	8	-1.3889-008	1.6613-008
34	9	9.1847-010	-1.8644-008	35	9	-7.3350-010	1.1027-008
34	10	-1.8206-008	6.6785-009	35	10	6.5923-010	1.9083-008
34	11	5.7636-009	1.1601-008	35	11	3.1498-009	-5.0448-009
34	12	6.7838-009	7.0620-010	35	12	-2.8245-009	-1.3917-008

TABLE C-1 (Cont'd)

HARMOGRAV

EARTH GRAVITATIONAL MODEL

Degree and Order n	m	Normalized Geopotential Coefficients $\bar{C}_{nm}$	$\bar{S}_{nm}$	Degree and Order n	m	Normalized Geopotential Coefficients $\bar{C}_{nm}$	$\bar{S}_{nm}$
35	13	-8.8203-009	9.7574-009	36	14	-1.3874-009	-7.3142-009
35	14	-4.4209-009	7.0312-010	36	15	-3.8893-009	-2.5758-009
35	15	-1.6346-008	-2.1497-009	36	16	3.0288-009	1.8781-009
35	16	-1.8464-008	-1.3978-008	36	17	1.2607-008	-9.4544-009
35	17	-1.7702-008	-1.0990-008	36	18	-3.6716-009	1.3848-008
35	18	-1.1438-008	-2.2028-008	36	19	-1.5926-008	-4.8045-009
35	19	9.6071-009	-1.4167-008	36	20	-1.3182-008	-4.5491-009
35	20	7.6495-009	-1.2424-009	36	21	6.1432-009	-1.0665-008
35	21	5.5997-009	2.1572-008	36	22	-2.1941-009	-8.4266-009
35	22	-6.9924-009	-6.8164-009	36	23	-6.2590-009	-4.9936-009
35	23	-6.1961-009	1.4978-009	36	24	1.7261-009	-6.0430-009
35	24	3.8859-009	-4.5141-009	36	25	7.4130-009	1.2027-008
35	25	1.7007-008	-1.6844-009	36	26	-3.0558-009	6.2052-009
35	26	1.3488-008	6.9427-009	36	27	-3.9464-010	1.7071-008
35	27	7.5052-009	-2.4568-010	36	28	6.7556-009	1.8210-008
35	28	9.9186-010	-3.7353-009	36	29	6.0063-009	1.0631-008
35	29	-1.3359-008	3.6744-009	36	30	-2.2387-008	-5.5624-009
35	30	-7.2105-009	1.7520-009	36	31	-3.1563-009	4.8261-009
35	31	1.7189-008	-2.9934-009	36	32	1.8600-008	-3.0196-009
35	32	-4.4453-011	-2.8624-009	36	33	-1.2172-009	-1.3351-009
35	33	-5.6402-009	-2.0311-008	36	34	-7.9841-009	-8.5717-009
35	34	-8.4139-009	-5.8825-009	36	35	7.8398-009	4.9381-009
35	35	-1.4546-009	-7.2126-009	36	36	2.2273-009	-6.1321-008
36	0	-1.6593-008					
36	1	-1.7728-008	-1.0032-008				
36	2	-4.5895-009	-2.0669-009				
36	3	-6.3408-009	3.4154-008				
36	4	2.4981-009	4.2447-009				
36	5	1.8914-008	-4.1839-008				
36	6	4.5116-009	2.4912-009				
36	7	-1.7199-008	9.7325-009				
36	8	1.9350-009	9.7232-011				
36	9	2.4268-008	-1.4723-008				
36	10	-7.8810-009	3.5871-009				
36	11	-1.4670-008	1.4502-008				
36	12	3.3416-009	-8.8792-009				
36	13	3.6863-009	1.0281-008				

HARMOGRAV

Appendix D

HARMOGRAV's Degree Variances

Gravity Anomaly Variances

(Unit = Mgals^2)

$$\sigma_n = \sum_{m=0}^{n} (\bar{A}_{nm}^{\ 2} + \bar{B}_{nm}^{\ 2})$$

Degree	Variance	Degree	Variance
2	18.61	20	4.73
3	28.51	21	6.08
4	13.32	22	5.22
5	17.35	23	4.76
6	25.60	24	6.74
7	21.42	25	5.44
8	9.06	26	5.50
9	10.91	27	5.30
10	11.73	28	5.31
11	12.88	29	5.16
12	6.28	30	4.47
13	5.31	31	5.29
14	7.82	32	5.80
15	6.50	33	7.77
16	4.59	34	5.36
17	7.92	35	8.40
18	7.75	36	7.19
19	4.59		

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Earth's Gravitational Potential

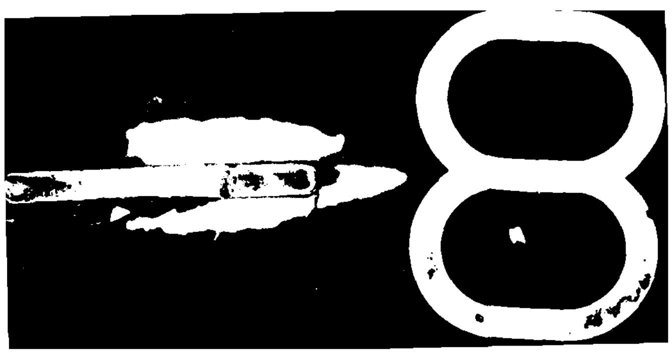
Gravity

Physical Geodesy

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A new way to estimate a composite earth gravity model, representing 5°x 5° equal area gravity anomalies, by harmonic coefficients of the earth's gravity potential is demonstrated. This earth gravity model represents a pure terrestrial gravitational potential, developed by conventional mathematical formulas. The observational data used in the development was restricted to mean gravity anomalies derived from surface gravity measurements. The mean gravity anomalies representing the unsurveyed sectors adjacent

20. to surveyed sectors are allowed to take on values which are determined from a previously derived potential function that was developed from all previously established anomaly values and from zero anomaly values for all unestablished sectors. As each new potential function is developed from the already established sector means, that function is used to compute and fix the mean anomaly values for the next step of unsurveyed adjacent sectors. Thus, by successively fixing the means of the adjacent sectors and by always holding to the originally observed sector values, a full set of fixed means and a final potential function can be developed.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